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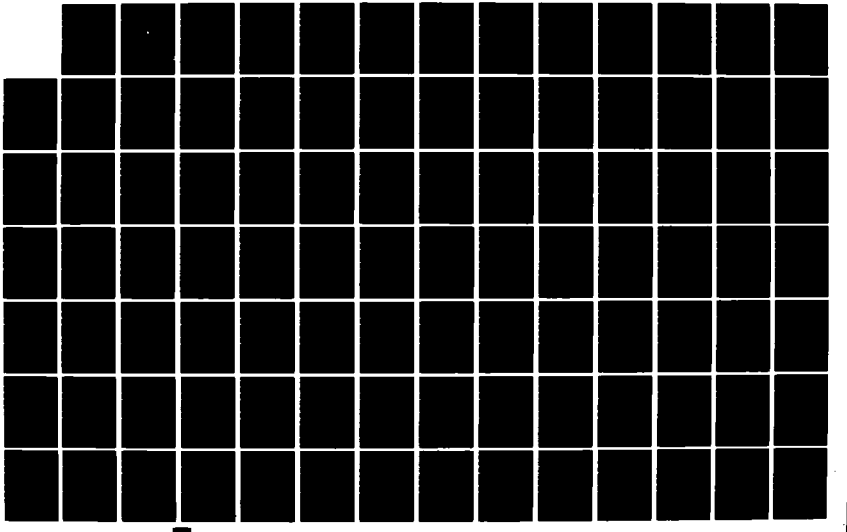

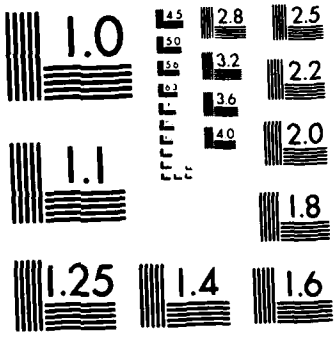

NAVAL POSTGRADUATE SCHOOL
Monterey, California

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THE EVOLUTION
OF
THE U.S. HELICOPTER INDUSTRY

by

Murray D. Sheil

December 1984

Thesis Co-advisors: D. C. Boger
J. E. Ferris

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The first production helicopter in the United States was produced by Sikorsky Aircraft (now a division of United Technologies) in 1941 as a direct result of a U.S. Army Air Corps requirement. Helicopter technology advanced rapidly, driven mainly by U.S. Department of Defense research and development funding. The business base expanded as commercial operators became more aware of helicopter capabilities made available

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The Evolution of the U.S. Helicopter Industry

by

Murray D. Sheil
Commander, Royal Australian Navy

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

The first production helicopter in the United States was produced by Sikorsky Aircraft (now a division of United Technologies) in 1941 as a direct result of a U.S. Army Air Corps requirement. Helicopter technology advanced rapidly, driven mainly by ~~U.S.~~ Department of Defense research and development funding. The business base expanded as commercial operators became more aware of helicopter capabilities made available through advancing technology. Many competitors were attracted to the industry, including a number from overseas. This thesis examines the growth of the U.S. helicopter industry and explores the issues that have led to the success or failure of the industry's competitors. A particular issue addressed is the role the Department of Defense has played in shaping the industry. The work concludes with an analysis of the current state of the industry and the prospects for its future.

TABLE OF CONTENTS

I. INTRODUCTION ---------- 14

A. BACKGROUND ---------- 14

B. RESEARCH QUESTIONS ---------- 17

1. Primary Research Question ---------- 17

2. Subsidiary Research Questions ---------- 17

C. RESEARCH METHODOLOGY ---------- 18

D. SCOPE OF STUDY ---------- 19

E. LIMITATIONS OF STUDY ---------- 19

F. ORGANIZATION OF STUDY ---------- 20

II. HISTORICAL BACKGROUND ---------- 23

A. INTRODUCTION ---------- 23

B. EARLY DEVELOPMENT OF HELICOPTER THEORY ----- 23

C. TRANSITION FROM THEORY TO PRACTICE --------- 25

D. THE BIRTH OF THE HELICOPTER INDUSTRY ------- 32

III. THE U.S. HELICOPTER INDUSTRY - DEVELOPMENT AND MARKETS ---------- 36

A. INTRODUCTION ---------- 36

B. MILITARY DEVELOPMENT ---------- 37

1. The Beginning - 1938 to 1950 ---------- 37

2. The Korean Conflict - 1950 to 1960 ----- 41

3. The Vietnam Conflict - 1960 to 1970 ---- 43

4. The Post Vietnam Era - 1970 to Present - 49

C. CIVIL DEVELOPMENT ---------- 51

1. The Autogiros ---------- 51

2. The Helicopters ---------- 52

D. SIZE AND COMPOSITION OF THE U.S. HELICOPTER INDUSTRY ---------- 61

E. THE GROWTH OF THE EUROPEAN THREAT TO U.S. MARKETS ---------- 65

IV. COMPETITORS IN THE HELICOPTER INDUSTRY --------- 74

A. INTRODUCTION ---------- 74

B. U.S. COMPETITORS ---------- 75

1. Sikorsky Aircraft ---------- 75

2. Bell Helicopter Textron Inc. ---------- 79

3. Boeing-Vertol ---------- 83

4. Hughes Helicopters Inc. ---------- 87

C. EUROPEAN COMPETITORS ---------- 90

1. Aerospatiale Helicopter Corporation ---- 90

2. Westland Helicopters Ltd. ---------- 92

3. Messerschmidtt-Boelkow-Blohm (MBB) ----- 97

4. The Agusta Group ---------- 101

D. SOVIET COMPETITIONS ---------- 105

E. OTHER U.S. COMPETITORS ---------- 109

1. Kaman Corporation ---------- 109

2. Robinson Helicopter Inc. ---------- 109

3. The Enstrom Helicopter Corporation ----- 109

4. Hiller Aviation, Inc. ---------- 110

5. Hynes Helicopter Inc. ---------- 111

F. SOME COMPETITORS WHO DID NOT SURVIVE ------- 111

1. Competitive Situation in 1945 ---------- 111
2. Platt-LePage ---------- 112
3. Bendix ---------- 112
4. Gyrodyne Company of America (GCA) ------ 113
5. Kellet ---------- 113
6. Firestone ---------- 113
7. Doman ---------- 114
8. Seibel-Cessna ---------- 114
9. Rotorcraft Co. ---------- 115
10. Other U.S. Companies ---------- 115

V. DEVELOPMENT OF THE HELICOPTER ENGINE ---------- 116
A. INTRODUCTION ---------- 116
B. PISTON ENGINES ---------- 117
C. FIRST GENERATION TURBINE ENGINES ---------- 118
D. SECOND GENERATION TURBINE ENGINES ---------- 121
E. THIRD GENERATION TURBINE ENGINES ---------- 122
F. CURRENT ENGINE PROGRAMS ---------- 123

VI. TECHNOLOGY DEVELOPMENT ---------- 127
A. INTRODUCTION ---------- 127
B. COMMERCIAL VS MILITARY DEVELOPMENT CYCLES -- 128
C. U.S. VS EUROPEAN DEVELOPMENT APPROACHES ---- 129
D. FUNDING OF HELICOPTER DEVELOPMENT ---------- 132
E. TECHNOLOGY TRANSFER ISSUES ---------- 137

VII. MILITARY REQUIREMENTS ---------- 140
A. INTRODUCTION ---------- 140

B. THE EARLY REQUIREMENTS ---------- 140

C. THE S-51 REPLACEMENT COMPETITION ---------- 142

D. AIR FORCE RESCUE HELICOPTER COMPETITION - 1950 ---------- 143

E. MARINE CORPS ASSAULT REQUIREMENT - 1951 ---- 144

F. THE NAVY INTERIM ASW REQUIREMENT ---------- 145

G. THE NAVY ASW MISSION REQUIREMENT ---------- 146

H. THE ARMY UTILITY HELICOPTER REQUIREMENT ---- 146

I. THE ARMY HELICOPTER TRANSPORT REQUIREMENT -- 148

J. THE ARMY LIGHT OBSERVATION HELICOPTER REQUIREMENT ---------- 149

K. THE ARMY ATTACK HELICOPTER REQUIREMENT ----- 152

1. The Early Attack Helicopters ---------- 153

2. The Purpose-Designed Attack Helicopter ---------- 155

L. THE ARMY UTILITY HELICOPTER REPLACEMENT ---- 158

M. SUMMARY ---------- 159

VIII. MANUFACTURER/GOVERNMENT RELATIONS AND MARKETING ISSUES ---------- 161

A. INTRODUCTION ---------- 161

B. MANUFACTURER/GOVERNMENT RELATIONS ---------- 161

C. GOVERNMENT SUPPORT OF PRODUCT MARKETING ---- 168

D. FOREIGN MILITARY SALES ---------- 171

E. FINANCING ---------- 172

F. INTERNATIONAL LICENSING ---------- 176

G. CO-PRODUCTION ---------- 179

IX. THE FUTURE OF HELICOPTERS ---------- 181

A. INTRODUCTION ---------- 181

B. TECHNOLOGICAL CHALLENGES ---------- 181

1. Aerodynamics and Structures ---------- 182

2. Propulsion Systems ---------- 183

3. Flight Controls and Avionics ---------- 184

4. Advanced Rotorcraft Configurations ----- 185

C. MILITARY DEVELOPMENTS ---------- 187

1. The Joint Services Advanced Vertical Lift Aircraft (JVX) ---------- 188

2. The U.S. Army Light Helicopter LHX Family ---------- 189

3. The Advanced Cargo Helicopter (ACH-XX) ---------- 191

D. THE FEDERAL AVIATION ADMINISTRATION (FAA) -- 191

E. CIVIL APPLICATIONS ---------- 192

1. Air Transportation ---------- 192

2. Forestry and Agriculture ---------- 193

3. Resource Exploration and Development --- 193

4. Construction ---------- 194

5. Public Service ---------- 194

F. THE FUTURE MARKETS-FORECASTS ---------- 195

G. COMPETITIVE SITUATION ---------- 199

X. CONCLUSIONS AND RECOMMENDATIONS ---------- 203

A. INTRODUCTION ---------- 203

B. CONCLUSIONS ---------- 204

1. U.S. Military Customers/Markets -------- 204

2. U.S. Commercial Customers/Markets ------ 205

3. Military Requirements ---------- 207
4. U.S. Competitors ---------- 208
5. Global Situation ---------- 210
6. Technology ---------- 211
C. RECOMMENDATIONS FOR FURTHER STUDY ---------- 214
APPENDIX A ---------- 215
APPENDIX B ---------- 232
LIST OF REFERENCES ---------- 244
INITIAL DISTRIBUTION LIST ---------- 247

LIST OF TABLES

1.	Change in World Production Shares 1970-1980 --	62
2.	U.S. Army/Navy RDT & E - Helicopters ---------	133
3.	Civil Aeronautics Research Funding Through Public Research Institutions-European Nations and United States ----------	134
4.	NASA Research and Development Budget Authority and the Aeronautical Component -----	136
5.	Medium-Term Fixed Export Credit Effective Interest Rates ----------	174
6.	Free World Helicopter Deliveries (Units) -----	196
7.	Sikorsky Ten-year Projection - Civil Helicopters ----------	199
A-1.	Free World Helicopter Production - Units -----	215
A-2.	U.S. Helicopter Production History-Units -----	217
A-3.	U.S. Helicopter Production History-Units -----	219
A-4.	Free World Market Share of U.S. Manufacturers ----------	221
A-5.	Free World Market Share of European Manufacturers ----------	222
A-6.	U.S. Helicopter Production-Units ----------	223
A-7.	U.S. Helicopter Production-Dollars Millions --	224
A-8.	U.S. Manufacturers' Share of U.S. Production ----------	225
A-9.	Helicopters Imported/Exported-Units ----------	227
A-10.	Helicopters Imported/Exported-Value ----------	228
A-11.	Civil Helicopters Imported by Origin-Units ---	229
A-12.	Helicopters Imported by Origin-Dollars Million ----------	230

A-13. Civil Helicopter Usage
(U.S., Canada, Puerto Rico) ---------- 231

LIST OF FIGURES

B-1. Free World Helicopter Production - Units ------ 232

B-2. U.S. Helicopter Production - Units ---------- 233

B-3. U.S. Helicopter Production - Units ---------- 234

B-4. U.S. Helicopter Production - Units ---------- 235

B-5. U.S. Helicopter Production - Dollars Million -- 236

B-6. U.S. Manufacturers Market Share of U.S. Production ---------- 237

B-7. Helicopters Imported/Exported - Units --------- 238

B-8. Helicopters Imported/Exported - Value --------- 239

B-9. Civil Helicopters Imported by Region - Units -- 240

B-10. Civil Helicopters Imported by Region - Value -- 241

B-11. Civil Helicopters Usage - U.S./Canada/ Puerto Rico ---------- 242

B-12. Growth of Aerospatiale Helicopter Division ---- 243

I. INTRODUCTION

A. BACKGROUND

When the Chinese developed a flying top in the fourth century BC, they began the saga of vertical flight. Progress was painfully slow, and it was not until 1907 when helicopters built by Breguet and Cornu in France achieved the distinction of genuine vertical flight. The early pioneers became convinced that the sole factor limiting helicopter development was the lack of a suitably powerful propulsion unit. When the Wright brothers demonstrated the viability of heavier-than-air powered flight in 1903, the prospects of rapid helicopter development appeared promising. In reality, however, the development of more powerful engines merely brought the early designers face to face with a myriad of unanticipated design problems that were to cause the helicopter industry to lag the fixed wing aviation industry by a span of thirty to forty years.

Early helicopter development was conducted in Russia, France, Germany, England, Spain, Italy, and the United States in the period 1900 to 1940. The first United States military contract for the construction of a helicopter was signed by Georges de Bothezat in 1921. This helicopter flew, but not well, and it did not lead to production. Some relatively successful results were obtained in France and

Germany in the late 1930s, mostly with helicopters designed by Professor Heinrich Focke, but European progress was delayed by the advent of World War II.

The helicopter industry was finally born in 1938 when the Dorsey Bill was presented in the United States House of Representatives, and shortly afterwards became Public Law 787, authorizing the expenditure of $2 million for the research and development of rotary wing aircraft. In 1939, Public Law 61, passed by the Seventy-Sixth Congress, appropriated $300,000 for helicopter development. [1:18]

Thus began a long history of United States military involvement in the shaping of the development and structure of the world helicopter industry. The first successful U.S. military helicopter contract was performed in 1940 by Igor Sikorsky who is generally regarded as the father of the helicopter industry. Sikorsky's XR-4 was delivered to the U.S. Army at Wright Field, Ohio in May, 1942. This success prompted considerable military interest, coming as it did during World War II, and a series of military contracts explored many helicopter applications.

Available technology constrained the industry until the advent of the Korean conflict stimulated rapid technological advancements, the most significant being the turbine engine, with its substantially superior power-to-weight ratio. Many United States manufacturers were attracted to the industry but few survived.

European helicopter development, delayed by the chaos following World War II, was stimulated by the transfer of United States helicopter technology through licensing agreements granted by the more successful U.S. companies. Four major European manufacturers emerged; Westland (England), Aerospatiale (France), Agusta (Italy), and Messerschmidtt-Boelkow-Blohm (MBB-Germany).

U.S. industry development continued with considerable military research and development sponsorship and four major U.S. manufacturers emerged; Sikorsky Aircraft, Bell Helicopters, Hughes Helicopters, and Boeing-Vertol. Many other companies, including such notable names as Lockheed, McDonnell, Kellet, Kaman, and many other smaller firms were unable to achieve military quantity production and did not survive as helicopter manufacturers.

Civil applications have been slow to develop and the civil market did not achieve significant proportions until the 1970s, when the off-shore oil rig support and corporate/executive markets blossomed.

The U.S. helicopter industry is small compared to the total United States aerospace industry. U.S. helicopter deliveries in 1982 were approximately $1.4 billion compared to U.S. civil transport sales of $6.2 billion and general aviation aircraft sales of $2.0 billion [Ref. 2]. Growth of the industry has been steady, albeit susceptible to the volatile requirements of the U.S. Department of Defense (DoD).

A significant trend has been the penetration of the U.S. commercial market by the European makers, notably Aerospatiale of France.

The U.S. helicopter industry is on the verge of its greatest challenge yet, the transition into the fourth generation of helicopter technology as a result of two significant military programs, the Joint Services Vertical Lift program (JVX) for the Navy and Marine Corps, and the Light Helicopter program (LHX) for the Army. Both programs offer substantial production quantities. The rewards for the winners of these technology advancing competitions will be continuing military workload and the application of this technology to civil derivatives leading to greater access to the civil market. The losers may not survive.

B. RESEARCH QUESTIONS

1. Primary Research Question

What are the critical factors that have affected the development and evolution of the U.S. helicopter industry?

2. Subsidiary Research Questions

a. First Subsidiary Research Question

What customer/market segments have declined or emerged and how have they affected the evolution of the U.S. helicopter industry?

b. Second Subsidiary Research Question

How have military requirements affected the U.S. helicopter industry?

c. Third Subsidiary Research Question

Who have the U.S. helicopter industry competitors been and what factors have led to their success or failure?

d. Fourth Subsidiary Research Question

How has the global helicopter industry affected or been affected by the U.S. helicopter industry?

e. How has technology growth affected the U.S. helicopter industry?

C. RESEARCH METHODOLOGY

The research effort for this thesis relied primarily on two data sources. The first was a comprehensive review of available published literature, in the form of relevant books, industry journals, periodicals, newspapers, and industry and trade association documents. Secondly, interviews were conducted with the strategic planning departments of the previously listed four major U.S. helicopter manufacturers. A valuable source of data and opinion was the American Helicopter Society (AHS), Washington D.C. This society was incorporated in June, 1943, with the constitutional purpose of "collecting, compiling, and disseminating information concerning the helicopter" [3:57]. In this way it set out to represent the industry as a whole, and as such was a valuable source of balanced industry comment and flavour.

D. SCOPE OF STUDY

The object of this research effort is the development of the U.S. helicopter industry. Considerable attention has been given to past U.S. industry history, in particular the impact of U.S. DoD requirements on the industry. This focus was dictated by a prior perception that the helicopter industry was shaped by the provision of military research and development funding. Technology growth was also considered in some detail but generally in the context of its impact on the strategic and business issues leading to competitive advantages or disadvantages.

E. LIMITATIONS OF STUDY

Given that the thesis focuses on commercial strategic and competitive issues, the company interviews were understandably guarded and non-attributable. They did serve to provide both a flavour to the written word unearthed during the literature review and a source of individual company product line development and statistical production data.

The thesis does not address the financial performance of the companies, the reasons for this being three-fold. Firstly, the major companies are all now subsidiaries or divisions of large corporations and accordingly their individual line-of-business financial data are buried inside consolidated financial statements. Secondly, the financial performance of any of the major firms is unlikely to be a significant

factor in the short term, there being an adequate source of corporate funds to overcome a transient and maybe unpredicted cash flow problem. Obviously, sustained poor financial performance would be cause for concern and, perhaps, ultimate company failure, but this would be the result of a deeper, underlying cause (e.g., failure to win production contracts). Thirdly, such research effort would have detracted from the primary focus, i.e., the impact of military requirements.

The thesis also does not address supply side issues. The resource base, in terms of raw materials, sub-contract supplies, labour, and capital, is an obvious contributor to the overall competitive situation but was considered to be beyond the scope of this effort, which focuses on the relationship between the prime manufacturers and their markets/customers.

F. ORGANIZATION OF STUDY

Chapter II provides an historical background of the early development of helicopter theory, providing some insight into those aerodynamic and technological factors that delayed the birth of the industry. The coverage is extended to the late 1930s/early 1940s when Igor Sikorsky produced the world's first viable production helicopter for the U.S. Army.

Chapter III describes in relatively general terms, the development of the U.S. helicopter industry and its market,

indicating the key developmental milestones and issues. It concludes with a quantitative analysis of the growth of the U.S. helicopter industry in the context of the free world industry and some detailed comment on the development of Aerospatiale of France.

Brief profiles of the major competitors are provided in Chapter IV, together with comments on companies that did not survive and a brief review of Soviet helicopter development.

The U.S. helicopter industry developed in generations (piston-engined and turbine-engined). The fourth generation will be introduced by the JVX and LHX programs. These issues are addressed in Chapter V.

Chapter VI explores the role of technology and the approach adopted by countries and makers to technology development. A consistent complaint of U.S. makers is their claim that European governments are more supportive of civil market oriented research and development than is the U.S. Government.

A consistent perception, both throughout the readings and the interviews, is the widely held view that the U.S. helicopter industry is driven by the U.S. DoD in its development of military requirements, this technology being transferred to civil derivatives of military airframes. This aspect is examined in Chapter VII.

Chapter VIII examines, in some less detail, financing, pricing, co-production, government incentives, and manufacturer/government relations.

The study concludes with Chapter IX, which is devoted to the future prospects of the industry, in terms of markets, product lines, technology, and competition.

The study conclusions are presented in Chapter X.

II. HISTORICAL BACKGROUND

A. INTRODUCTION

The development of the helicopter has taken place over many years. However, as depicted in Alvin Tofler's "Future Shock", [Ref. 4], the growth of knowledge has been far from linear. The transition from fantasy to theory, from theory to first stumbling flights, thence to practical reality and finally to today's technologically complex helicopter systems has been fraught with difficulties and frustrations. This chapter will briefly address the early development of helicopter theory and the transition to practicality, in order that the growth restraining factors of the industry can be better understood.

B. EARLY DEVELOPMENT OF HELICOPTER THEORY

When the Chinese developed a flying top that could fly under its own power in the fourth century B.C., they began the saga of vertical flight. The concept remained as a toy until Leonardo da Vinci proposed the first full scale helicopter in 1483 with his now famour design for a lifting screw (the "helix"). This one event aside, the idea of the helicopter did not gain momentum until 1768 when a French mathematician, J.P. Paucton proposed that the classic Archimedean water lifting screw could be used for human flight. Sixteen years later, in 1784, two Frenchmen, Launoy

and Bienvenu, developed the first toy helicopter with a rotary wing, able to take off under its own power. It was not realized at the time, but the device had overcome two fundamental barriers to helicopter development. It had a self contained power source, and the use of counterrotating propellers overcame the problem of torque, the force that tends to drive the body of a single rotor device in the opposite direction to that of the turning shaft [1:18]. Lacking a suitable power source, they were forced to put aside their ideas for full scale development.

An Englishman, Sir George Cayley, inspired by the toy helicopter, is credited by many with producing the first modern helicopter design in the early 1800s. This design used counterrotating rotors on either side of a canvas covered fuselage, with an additional pair of pusher propellers at the rear for forward flight. Cayley, also, did not get his design off the drawing board, realizing that heavier-than-air vertical flight required a more powerful propulsion system than was available at the time.

In 1878 an Italian, Forlanini, built a steam powered model helicopter that flew for twenty seconds at forty feet. This was followed in the 1880s by Thomas Alva Edison who attempted to achieve vertical flight by mounting experimental rotors on a vertical shaft powered by an electric motor. His experiment failed but he continued to believe in the helicopter, concluding, like many before and after him, that

a successful helicopter would not be built until an engine that weighed no more than forty-two to sixty-three ounces for each horsepower produced could be developed [1:5]. He did, however, predict that

> Whatever progress the aeroplane might make, the helicopter will come to be taken up by the advanced students of aeronautics. [5:25]

Early experimenters, believing that propulsion power was the only obstacle, were rewarded in the early 1900s with the development of much more powerful gasoline engines. These engines that enabled the Wright brothers to make the first powered flight in 1903 did indeed permit the early pioneers of vertical flight to move from theory to reality. What they also did, however, was to bring the designers face to face with the other problems of stability and control, hitherto not really considered.

C. TRANSITION FROM THEORY TO PRACTICE

In 1907, Breguet (of France) built a helicopter that rose vertically to a height of two feet and remained there for two minutes. This tethered flight was followed in 1908 and 1909 by two more models but all were plagued with a power-to-weight ratio problem, as well as difficulties with stability and control. Paul Cornu of France, is credited with the first helicopter "free-flight" when his aircraft rose to one to five feet for twenty seconds in 1907, but his design experienced the same power, stability, and control problems.

In the early 1900s, Igor Ivanovich Sikorsky, a young Russian from Kiev had been dreaming about helicopter flight for years. He firmly committed himself to the creation of flying machines and chose the helicopter as the "likeliest instrument for his ambition" [5:32]. His first two designs in 1909 and 1910 were not successful but he remained convinced of the reality of his dream. As did others before him, he realized that powerplant availability was a problem and transferred his attention to fixed wing aircraft, achieving success with the 9000 lb. Bolshoi-Balitsky, the world's first four-engined aircraft. He was not to return to helicopters until the 1930s, but his return at that time would launch the helicopter industry.

In the meantime, many other efforts contributed to the development of helicopter theory and practice. During World War I, Lieutenant Stephan von Petroczy of the Austrian Army Balloon Corps and Professor Theodor von Karmon built an electrically powered machine. Whilst not totally successful, this experiment provided some insight into the importance of centre-of-gravity as related to stability and control.

Then, as a significant forerunner of the way the industry was to later achieve its birth, the U.S. Army Air Corps undertook its first important vertical flight program. Army interest had begun in 1918 just after the Armistice, when the Army foresaw great possibilities for "a machine capable of up-and-down flight and hence operation from restricted

areas" [6:88]. In 1921, the Army commenced a helicopter project, funding George de Bothezat, a refugee from revolution-torn Russia. His machine flew on December 18, 1922, seven months behind schedule, rising to a height of thirty feet with its 220 horsepower engine and its 3600 lb. airframe. The Army, however, was unconvinced of the practicality of the design and cancelled the project after spending some $200,000. An Army report on the project drew attention to the inherent dissymmetry of his multiple rotor-machine (should mechanical failure occur) and its general mechanical complexity, stating that:

> Until these defects can be eliminated, the future development of the helicopter proper appears to rest rather in the single-screw type and the reasons for this are at least strong enough to warrant the building and testing of such a type before multiple-screw types are adopted. [6:88]

The paper, in recognizing that the Army saw a need and a use for the helicopter, noted that the de Bothezat helicopter contributed a definite step forward in helicopter progress that could not have been achieved without the expenditure for building a machine and flying it.

Several helicopters were built in the United States in the 1920s by Emile Berliner (the inventor cf the Victor phonograph) and his son Henry. Like many predecessors, they chose to solve the torque problem by using counterrotating rotors. They experimented over a five-year period but gave up in the face of problems they could not resolve.

On May 4, 1924, Etienne Oehmichen (France) succeeded in flying the first one kilometer closed circuit course and collected 90,000 francs prize money for his efforts. His helicopter had four main rotors, each with two blades, and five small horizontal variable/reversible pitch propellers.

On April 18, 1924, Marquis Pateras Pescara (Spain) established a world straight line distance record of 736 meters in his four bladed biplane rotor system machine. The significant contribution of this machine was the ability of the rotors to turn freely in the event of an engine failure. As the aircraft neared the ground, the pitch of the blades was increased to use the remainder of the stored energy in the rotor system and land softly. This concept is called autorotation, and is still an important feature of the modern helicopter.

Dutch engineer A. G. von Baumhauer was one of the first pioneers to use a counterrotating tail rotor to compensate the single main rotor torque. He also developed the swash plate system, a device (still in use today) that varied the blade angle of the rotor periodically to stabilize and control the machine [1:12].

In 1930, Italy's Corridion D'Ascanio set many records with his unique helicopter design that featured another significant technological development, the system for feathering the main rotor blades. This involved the development of a hinge system that allowed the blades to be rotated

around their longitudinal axis, thereby changing the pitch angle of the blades and changing the lift. It also featured counterrotating blades but its overall complexity prevented complete success.

Nicolas Florine, of Belgium, developed a radically new design in the early 1930s. This design featured rotors located at the fore and aft ends of the fuselage and it first flew in April, 1933. The design was the forerunner of the tandem rotor helicopter configuration still being used today to meet many heavy lift requirements [1:14].

In 1935, Breguet returned to helicopters and, with Rene Dorand, achieved with the Breguet-Dorand Giroplane what many consider to be the first real helicopter. The Giroplane had two four-bladed counterrotating rotors, a system permitting each blade to adjust itself in flight to the dynamic forces to which it was subjected.

Simultaneously, Professor Henrich Focke was achieving considerable success in Germany, establishing a series of world records for speed, altitude, endurance and controlled flight. His helicopter had two rotors, each having three articulated blades, mounted at the end of each of two wings. Focke considered this the best way to overcome torque and to eliminate vibration inherent in the design that mounted rotors one on top of the other. The success of his machine elevated the helicopter to a new plane of public awareness [1:15].

The dream of vertical flight might not have been realized but for the work of a young Spanish aristocrat named Juan de la Cierva, who "made a breakthrough that brought the elusive helicopter to the threshold of reality" [5:51]. After many years of experimentation that commenced in 1910, he developed the la Cierva autogiro that resolved the problem of relieving the high dynamic stresses developed at the rotor hub of rigidly mounted blades. The autogiro, having a free-wheeling, unpowered rotor, did not encounter the torque problem that plagued early helicopter pioneers but it retain two other problems, i.e., the gyroscopic resistance to being tilted out of its plane of rotation and the inequality of lift generated by the advancing blades and the retreating blades. To counter these stresses, la Cierva developed the flapping hinge and the lag-lead hinge and by 1927 had successfully incorporated his articulated rotor design into practical flying machines, thus passing out of the experimental stage. It was perhaps la Cierva's work that led Breguet to incorporate the articulated rotor into his successful 1935 giroplane.

Owing to British Air Ministry interest and funding, la Cierva had located himself in England. His manufacturing company was unable to meet demand for his inventive machine, although it produced ninety machines. In the late 1920s he granted production licenses to foreign manufacturers, including Japan (where 240 were built), France, Germany and Russia.

Airplane builder Harold Pitcairn bought the United States franchise and built 58 machines before sublicensing the Kellet brothers, who produced a further 22 machines. The machine was put to many uses that will be explored in Chapter III. [5:61]

The craft was given official recognition in 1931 when President Herbert C. Hoover presented the Collier Trophy to Harold Pitcairn for the "greatest achievement in aviation" for bringing the la Cierva autogiro to the United States. The design was further improved in the United States and the autogiro achieved great civil success, to the point where the United States Department of Commerce authorized development of a "roadable" autogiro that could be used on the road as well as in the air. This machine flew in 1936. A combination of economic conditions arising from the depression and high operating costs relative to conventional craft spelt the end for the autogiro.

> But if this strange machine with whirling wings was showing signs of being an economic and technological misfit, its developers had achieved at least one signal feat. For by solving the autogiro's problems one by one, la Cierva and his colleagues had opened the way at last for the practical helicopter. [1:36]

So by the end of the 1930s problems such as the lack of power, stability, control and torque had largely been overcome. All the significant technological breakthroughs had been made and the conceptual designs tried and tested in a myriad of different models throughout the United States and

Europe. The helicopter industry was waiting only for the integration of these concepts into a single machine. The man who provided this skill was Igor Sikorsky.

D. THE BIRTH OF THE HELICOPTER INDUSTRY

Igor Sikorsky, after temporarily giving up his helicopter ambitions in 1910, achieved considerable success in Russia as an aircraft designer during World War I. Following the Communist revolution of 1917 he lived in Paris for a while before proceeding to the United States. After some hard times, he founded the Sikorsky Aeroengineering Corporation in 1923, using borrowed money. The corporation began building the S-29A, an all metal twin engine transport. Over the next few years Sikorsky produced nine planes of various types but the corporation did not achieve great success until 1928, when the S-38 amphibian won wide acclaim. By 1929, Sikorsky was producing a much larger flying boat for Pan American Airways and Sikorsky renamed his company the Sikorsky Aviation Corporation and moved his plant to Stratford, Connecticut.

At this time, the company ran into financial difficulties and became first a subsidiary and then a division of the United Aircraft Corporation. This action provided him the opportunity to return to his dream of the helicopter. In late 1930 he wrote a memo to the management of United Aircraft, stating that,

> ...a helicopter that could land on the top of buildings, on ships, and in tiny parks could be built. He urged

> the company to develop in a reasonable and economic way its own type of helicopter. [5:78]

The onset of the depression destroyed any chance his proposal may have had and his company continued to achieve success in the fixed wing field. He continued his private efforts with helicopters, however. The continuation of the depression and increasing competition in the fixed wing field led to a decision, in 1938, by United Aircraft, to close down the Sikorsky division. However, the company did suggest that it would be open to the undertaking of a personal research project by Igor Sikorsky. Sikorsky immediately suggested the helicopter and requested that his team of expert engineers be retained.

Sikorsky had given much thought to helicopter configuration and finally decided to pursue an idea that he had patented several years earlier, that of a single main rotor and a small vertical tail rotor. The technology of the autogiro was also crucial to his work, with Sikorsky pointing out several years later that the

> ...The autogiro was the important missing link between the fixed wing concept and the helicopter concept. Without a doubt, the technology of the rotor head and blade, developed for the autogiro, was of significant use in the development of the helicopter. [1:48]

After much company funded work, the result of Sikorsky's efforts was rolled out on September 14, 1939. The first flight, although only a few inches and for a few minutes, occurred on that day. Sikorsky then began a series of

"hit-or-miss" alterations to dampen vibrations and balance the flight controls. On May 13, 1940, Sikorsky achieved the first free flight of his helicopter and Sikorsky's secret became public as the now famous VS-300 and the prototype of the world's first viable production helicopter.

The U.S. Army Air Corps had cancelled the de Bothezat helicopter project in the mid 1920s and Army enthusiasm for helicopter development had waned for several years. W. Laurence LePage (an engineer for the Pitcairn Autogiro Company and later for the Kellet Autogiro Company) and Havilland H. Platt (a mechanical engineer from New York), formed a company in 1938 for the express purpose of building a vertical flight capable aircraft. This alliance produced the Platt-LePage helicopter, the PL-3, and led to an Army contract on July 19, 1940, for the Army's second helicopter, the Platt-LePage XR-1. The Army also let contracts with the Kellet Autogiro Corporation for the XR-2 and the XR-3 autogiros.

But the Army was not satisfied with just one type and expressed interest in the Sikorsky VS-300. In July 1940, Captain "Frank" Gregory, of the Army, arrived at Sikorsky to test fly the VS-300. This event was significant for the helicopter industry because Gregory was the project officer for the embryo United States Army Helicopter Program. As a result of this flight, Gregory recommended that the Army sponsor the development of the VS-300, despite a commitment

to the Platt-LePage XR-1. Sikorsky was provided with a contract and $50,000 to b ld an experimental helicopter (the XR-4) for the Army Air Corps. The XR-4 was to be twice the size and twice as powerful as the VS-300. The Platt-LePage machine, because of its size, had to undergo many developmental changes while Sikorsky was able to make definite progress with his XR-4 design. The XR-4 was finally delivered to the Army Air Corps at Wright Field, Dayton, Ohio, after a spectacular five-day, sixteen-hop delivery flight that broke nearly all existing helicopter flying records.

In December, 1942, after the completion of extensive testing, the Army contracted for production to begin and also placed an order for a new larger model, the XR-5. Shortly after, in April, 1943, the Army requested yet another version, the XR-6. Meanwhile, the Platt-LePage experimental model was encountering difficulties and did not win a production contract. In Germany, Allied bombing raids were disrupting the planned production of Henrich Focke's FA-123 helicopter. Through this combination of events, and a clearly technologically superior product, Sikorsky was able to take an early lead in helicopter design and manufacturing. Sikorsky had established an early but significant competitive advantage and the helicopter industry had been born [5:84].

III. THE U.S. HELICOPTER INDUSTRY - DEVELOPMENT AND MARKETS

A. INTRODUCTION

The analysis of the development of the U.S. helicopter industry and its markets presents a dilemma. The growth of the industry is conceptually simple, with key growth milestones being dictated by major military events, i.e., World War II, the Korean conflict, and the Vietnam conflict, and with the commercial/civil helicopter users accepting minimally adapted military derivatives for a variety of applications (at least for the first thirty years of the industry until the 1950s).

Within that simplistic context, however, the detail of industry growth is incredibly complex, with the major manufacturers presenting a myriad of proposals for the numerous military competitions. It was tempting, when conducting this analysis, to describe every procurement in detail, but it soon became apparent that this approach would disguise the key events and issues leading to industry growth. Accordingly, the discussion that follows addresses only those events that have contributed significantly to that industry growth, and the astute or well-informed reader may consider that several events have been omitted.

B. MILITARY DEVELOPMENT

1. The Beginning - 1938 to 1950

The helicopter industry was initiated when the Dorsey Bill was presented in the House of Representatives in 1938. It soon became Public Law 787 and authorized the expenditure of $2 million for the research and development of helicopters. The following year Public Law 61 was passed by the Seventy-sixth Congress, appropriating $300,000 for the purpose of developing the helicopter [1:18]. This rapidly led to the award of military contracts to the Platt-LePage Aircraft Company and the Vought-Sikorsky Division of United Aircraft. Platt-LePage was unsuccessful but Igor Sikorsky won production contracts from the Army for his R4, R5 and R6 series helicopters, having previously developed the VS-300 helicopter with company funds. These events demonstrated three characteristics of the industry that have remained dominant throughout its life: the driving of the industry by military conflicts (in this case, World War II), the role of the military in specifying and dictating military requirements, and the military tendency to order back-up or parallel production to reduce program risk.

In Europe, pre-war helicopter technological progress had been halted by World War II. The early post-war attempts by Breguet (France) and Focke (Germany) ended in failures. In the United States, however, the U.S. designers quickly found themselves in the position of being world design and

production leaders. By V-J day (September, 1945) Sikorsky had produced 617 helicopters, the only manufacturer world-wide to have entered production [1:29]. During this period many helicopter applications were explored, ranging from the dropping of munitions, emergency medical and rescue use, mail deliveries, aerial photography, shipborne operations on the Army transport BUNKER HILL, amphibious operations (with floats), mosquito spraying, rescue hoist operations, construction work lifting, wire laying, and off-shore operations (in support of floating repair depots off Okinawa). Whilst these roles were well demonstrated most were not yet practical or economical due to payload restrictions [1:30].

By the time World War II ended, Sikorsky (having produced 617 aircraft for the military) had been joined by Bell (just completing its third prototype, the Model 30), Piasecki (flying the PV-3, the origin of the well-known Boeing-Vertol family of tandem rotor helicopters), Hiller (developing the KH-44, the first co-axial helicopter in the United States), and several other companies (Platt-LePage, Kellet, Bendix, Firestone and GCA, all developing their own unique prototypes) [7:154].

In 1942, Igor Sikorsky had predicted that in the future hundreds of thousands of helicopters would be produced at prices comparable to those of automobiles. This was a similar hope that Harold Pitcairn had held for his autogiro in the 1930s, but the dream had not been supported by

technology. With more than 70 companies working at helicopter development in the mid-1940s, technology had advanced considerably and there was great interest in the establishment of short haul helicopter services. Even the Greyhound Bus Company had filed an application to start an intercity helicopter service [5:99]. However, only a select few of the many design efforts were to succeed.

Sikorsky had already established his production capability by the end of World War II. Piasecki made progress with his PV-3 tandem rotor design. By spreading the load between two rotors, each rotor would be smaller and simpler than an equivalent lift single rotor. Additionally, cargo could be loaded almost anywhere in the long "flying banana" shaped fuselage without upsetting the centre-of-gravity. The concept also proved very attractive to Navy and Marine Vertical Replenishment (Vertrep) pilots because the aircraft could be hovered out-of-wind (the single rotor design of Sikorsky being sensitive to wind direction). These design concepts were sufficiently important to allow Piasecki to win important contracts for his tandem rotor designs of the HRP-1 "Flying Banana" that saw Navy, Marine and Coast Guard use.

The Navy version was evaluated for anti-submarine warfare (ASW) use [8:260]. Over the next two decades, the proven tandem concept would evolve into a variety of capable, multi-purpose helicopters produced in large quantities [5:100].

Arthur Young produced the Bell Model 30 for Bell Aircraft Corporation. The Bell design was similar to the Sikorsky single main rotor/single tail rotor but employed only a two-bladed rotor system. Being very simple, this helicopter could be produced very cheaply and soon evolved into the Bell Model 47. It was the first helicopter to achieve civil certification, in 1946.

Stanley Hiller formed his own company, and after experiments with co-axial designs, he developed his innovative and highly successful "rotormatic" rotor system [1:35] for use on the conventional single main rotor design approach. His Model 360 became successful, achieving civil certification in 1948.

Charles Kaman adopted the intermeshing rotor principle employed previously by Flettner in Germany in the 1930s. He had proposed this approach to United Aircraft, when he had been employed as Chief Aerodynamicist, but was refused, owing to the Sikorsky commitment to a single rotor design. He formed his own company in the late 1940s and was persuasive enough to win contracts from the Navy, Air Force, and Marines [5:102].

By 1949, a new generation of helicopters had been produced and five helicopters had received civil certification: the Sikorsky S-51 and S-52, the Hiller 360, the Kaman 190 and the Bell 47. On November 19, 1949, the Sikorsky H-19 made its first flight and proved it could carry 10

passengers and a crew of two more than 350 miles. This aircraft made possible, for the first time, a serious consideration of vertical envelopment of battlefields by helicopter borne troops [9:45]. The Sikorsky H-19 (commercial designation S-55) had been produced as a contract modification to an Air Force contract for the production of the Sikorsky S-51, which had initially been produced using company funds following the decline of military orders after World War II. This sequence of events was crucial to Sikorsky, leading to a production of nearly 2000 H-19/S-55's and access to further development contracts. It also led, ultimately, to Sikorsky's dominance in the ASW helicopter market.

By the end of the 1940s, almost 1000 helicopters had been produced and used in many military applications. The Marines, using the Piasecki "Flying Bananas", had experimented with the vertical envelopment concept, but the Army was prevented from using this aircraft in the battlefield by a bureaucracy that determined that Army aviation was restricted to aircraft weighing two tons or less.

2. The Korean Conflict - 1950 to 1960

When the Korean conflict broke out, the early helicopters were used for scouting. These were primarily Sikorsky S-51s that were not suited to medical evacuation. Between the wars the Army Medical Corps had developed the Mobile Army Surgical Hospital (MASH) concept. In so doing, they sponsored the Bell 47 observation and medical evacuation

helicopter. This private venture helicopter had been produced by Bell in large numbers in anticipation of a civil market that did not eventuate. Thus, when required in large numbers for the Army, the Bell 47 was able to defeat its only competitor, the Sikorsky S-52-1 (a development of the early Sikorsky R6) which was not production ready.

Hiller was also able to capitalize on the Korean conflict with a military version of his commercial Hiller 360, the Army H-23 Raven which was used extensively for observation, casualty evacuation, and general utility purposes.

By the end of the Korean Conflict in mid 1953, Bell had produced more than 1200 helicopters, Piasecki about 380, Sikorsky about 1350 and Hiller about 530. The Korean War had established the use of the battlefield helicopter, primarily in the medical and transportation roles and had given Sikorsky, Bell, Hiller, and Piasecki significant military production contracts. Further, the product line orientation of the companies was also established with Sikorsky and Piasecki producing larger, more complex helicopters and Bell and Hiller producing light simple helicopters.

The French experience in Indochina during the same period saw the use of a number of Sikorsky H-5ls and the larger H-19s, and two Hiller 360s. Their contribution to the war was not significant in material terms, being used almost exclusively for medical evacuation missions but the experience had a profound effect on the French military, who

used helicopters extensively in the Algerian theatre. By the time of the Algerian cease fire in 1962,

> The French had concentrated no less than six hundred helicopters in that country: 380 troop carrying craft of the H-34 and Vertol H-21 type; 21 medium craft of the S-34 and H-19 type and about 200 light helicopters mainly of the Alouette type. The French also had experience with arming these helicopters with a variety of guns and rockets. [8:3]

The French began a strong domestic helicopter industry in this period but British production relied mainly on licensed production of Sikorsky-developed machines. Whilst the U.S. Marines had conducted the first "vertical assault" exercises with helicopters as early as 1948, the British launched the first combat helicopter assault in November 1956 in the Suez. British-produced Sikorsky licensed helicopters were used in "police" operations in Africa and Asia, Kuwait, Tanganyika, Malaysia, Sarawak, Sabah, and Borneo [8:8].

3. The Vietnam Conflict - 1960 to 1970

The final military transition to helicopters came with the Vietnam war. This conflict provided the greatest single impetus to the world helicopter industry. The period after Korea and before Vietnam had seen an increasing military interest in the concept of "air mobility" and the helicopter war. Sikorsky and Piasecki continued to compete in the heavy helicopter arena. Piasecki had won a 1950 competition for an Air Force air rescue helicopter with the H-21 Workhorse. The Sikorsky S-58 (military designation

H-34) was produced concurrently under an Air Force contract modification to the previous Sikorsky H-19 contract. The demands of the Vietnam War ensured that both companies would receive substantial production orders. [1:37]

The arrival of 32 U.S. Army H-21 helicopters in Vietnam in December, 1961,

> ...was the first major symbol of United States combat power in Vietnam; and it was the beginning of a new era of air mobility in the United States Army. [8:8]

These helicopters were joined in April, 1962, by a Marine helicopter squadron of Sikorsky H-34s. By the late 1960s there were several thousand helicopters in South Vietnam. In late 1961, Secretary of Defense McNamara had tasked the Army to study its aviation requirements. The resulting Howze Board report led to the establishment of the Army's 1st Air Cavalry Division (Air Mobile) which deployed to Vietnam in 1965, with some 430 helicopters [8:9]

The early helicopters in Vietnam were not armoured and lacked power. However, the Army, aware of this shortcoming in its emerging battlefield helicopter concept, had sponsored engine development programs aimed at producing lightweight turbine engines especially for helicopters. These programs ultimately produced the Allison T-63, the Avco-Lycoming T-53, and the General Electric T-58 engines. The first turbine helicopter was the Kaman 225, which appeared in 1951, but America's first production turbine-powered helicopter did not appear until 1958 (the improved

Kaman 225 pilot rescue helicopter procured by the Air Force as the H-43 Huskie which saw Vietnam service and was Kaman's first long production run).

The mid 1960s saw a new generation of helicopters in Vietnam, as the manufacturers and the military took advantage of the new turbine engines. Boeing-Vertol, successor to the company founded by Piasecki in 1945, replaced the H-21 with two new turbine-powered transports, the CH-46 Sea Knight (designed for Marine and Navy shipborne use and capable of lifting 25 troops), and the larger CH-47 Chinook (designed for the Army and with a 45-troop capacity). Both aircraft relied on the prior Piasecki tandem rotor experience. Sikorsky produced a huge heavy lift aircraft, the twin turbo-shaft powered CH-54 Sky Crane. This aircraft had its roots in an earlier Navy contract that had produced the Sikorsky S-56 (CH-37) which in turn had led to a private venture heavy lift helicopter, the S-60. Sikorsky achieved further success in this period with two large twin-turbine helicopters, the H-3 and the H-53. The H-3 was designed to replace the Sikorsky H-34, whilst the H-53 was a heavy assault version of the Sky Crane [5:140].

The smallest helicopters in the Vietnam conflict were the light observation helicopters (LOHs). This task had previously been conducted by the Bell 47 and the Hiller 360. The Army conducted a competition for the LOH in the mid 1960s which was won by the Hughes OH-6A Cayuse with a

very aggressive pricing strategy. This event marked the entry of Hughes into quantity helicopter production. The two unsuccessful entrants were Bell and Hiller. Bell was able to commercialize its unsuccessful OH-4A as the very successful Bell Jet Ranger series. This helicopter subsequently won a follow-on contract for the LOH as the Bell OH-58 against the Hughes OH-6A.

The most visibly successful helicopter of the Vietnam war first flew at Bell in 1956. It was the simple turbine-powered utility helicopter, the UH-1 Huey. As with the previous Bell 47, Bell demonstrated the ability to continually improve the aircraft and it remained in full scale production for more than twenty years. The Huey superseded the Bell 47 MASH helicopter but it was rapidly assigned to more combative duties. The Huey was initially "jury rigged" with rockets and cannons in the field but factory equipped gunships arrived in 1963 [5:147]. These were too slow to be effective and the Advanced Aerial Fire Support System (AAFSS) project was initiated. This development contract was won by a newcomer, Lockheed. The Army contracted for an interim gunship, won by Bell with their privately funded Cobra, which reached the war in 1967 [5:150].

The American helicopter industry expanded dramatically to produce the surge of helicopter requirements for Vietnam. In their peak year during the war Boeing's Vertol division built 398 CH-46s and CH47s, Hughes delivered 1129

OH-6As and TH-55s, while Bell built 2485 helicopters in one year (UH-1s, AH-1s, and TH-13s). In addition, these firms were producing helicopters for civil use and foreign military services. Sikorsky produced its maximum output in 1957 (467 H-19s, CH-37s and CH-34s) but during the Vietnam war produced fewer but larger machines, including the CH-53 and the CH-54. [8:9]

Thus, the U.S. had a very firm grip on the helicopter market at the end of the Vietnam conflict, but, in addition to the material losses of the conflict (some 4,112 helicopters), a more subtle commercial loss occurred. Up until this time, the major U.S. makers, particularly Bell, Boeing-Vertol, and Sikorsky, had granted overseas licenses to European makers. This factor, allied with the U.S. industry commitment to support the Vietnam conflict with massive military helicopter production, caused a neglect of the export civil market, allowing the European makers to gradually penetrate both the European and domestic U.S. markets [10:148].

At the Vietnam cease-fire in January, 1973, the major U.S. military helicopter makers were: Sikorsky (who had established a dominant position in the ASW market with the S-61 Sea King series, as well as a strong position in the heavy lift and Marine assault markets with the CH-54A and the CH-53), Boeing-Vertol (with the CH-47 Chinook Army and CH-46 Sea Knight Marine Corps transports), Bell (with the Huey and the Cobra), Hughes (with the OH-6A Cayuse and the

Hughes 269/TH-55 Osage trainer), and Kaman (with the H-43B Huskie for Air Force crash rescue).

During this period military requirements responded to advancing technology in the area of ASW, with Sikorsky emerging the victor in competitions first against Piasecki with his tandem rotor designs and then against Bell who had won a 1950 competition with the tandem rotor HSL ASW design. Bell was not able to produce this helicopter and the Sikorsky S-58/H-34 became the Navy's standard ASW helicopter. Sikorsky was then able to upgrade the H-34 by an engineering change proposal to the S-61 Sea King (SH-3) without the requirement to compete. In the late 1960s, budget constraints led to the decommissioning of ASW carriers and resulted in the consolidation of the ASW squadrons with the fighter and attack squadrons in Air Groups on the remaining carriers. This resulted in the S-61 carrying out not only ASW duties but also plane guard/rescue tasks, displacing the rescue helicopter, the Kaman UH-2. The failure of another ASW program, the Drone AntiSubmarine Helicopter (DASH) program, left Navy destroyers without an ASW capability. This provided an opportunity for Kaman to nodify the UH-2 to the SH-2 Light Airborne Multi Purpose Systems (LAMPS) Phase I helicopter for the Navy.

At the end of the Vietnam conflict in 1973, Sikorsky, Boeing-Vertol, Bell, and Kaman had survived. Hughes had entered the market aggressively, whilst Hiller had been all

but eliminated by the Hughes entry. Lockheed had attempted to enter with its significant win in the AAFSS competition with the AH-56A Cheyenne, but, faced with many technical, economic, and political problems, was not able to bring the Cheyenne to fruition.

4. The Post Vietnam Era - 1970 to Present

Whilst the survivors had all had long production runs, the post Vietnam era saw a decline in the number of military orders. Sikorsky only had the S-61 Sea King, the CH-54 Sky Crane, and the CH-53 Sea Stallion, all in limited or late production, Boeing-Vertol's production was limited to the CH-47 Chinook, and Hughes had no new military orders in the offing. Bell alone had received a number of orders, for further UH-1 Hueys, AH-1 Cobras, and OH-58 Kiowa reconnaissance helicopters.

The 1970s saw a number of important competitions. The Army held a competition for the Utility Tactical Transport Aircraft System (UTTAS) helicopter to replace the Huey. The design competition was won by Sikorsky and Boeing-Vertol, who were then contracted for prototype development. Sikorsky, in what amounted to a make or break effort, won the fly-off in 1976 with the UH-60 Black Hawk, leading to quantity production with a multi-year contract. This was followed by a Navy requirement for the Phase III LAMPS ASW helicopter. Whilst the requirement was competed, Sikorsky easily won the competition with the navalized Black Hawk. An Air Force

requirement for a search and rescue helicopter is also likely, with Sikorsky being most favoured to win with yet another Black Hawk derivative.

The Sikorsky focus on the heavy end of the market paid dividends when it was able to win a contract in 1973 to develop the CH-53 series to the huge CH-53E Super Stallion by the addition of a third engine. The original design of this series was built with this option in mind. The CH-53E, provided to the Navy and the Marine Corps, is the heaviest heavy lift helicopter produced in the free world.

The other significant post Vietnam competition was the Army requirement for an Advanced Attack Helicopter (AAH). This program, designed to supersede the ill-fated Lockheed AH-56A Cheyenne, was won by the Hughes AH-64 Apache against the Bell YAH-63 in December, 1976. This win has assured the survival of Hughes and was significant enough to lead to the acquisition of Hughes by the McDonnell Douglas Corporation in January, 1984.

Bell has recently won a contract to upgrade the large Army fleet of OH-58 helicopters to the OH-58D standard in the Army Helicopter Improvement Program (AHIP), winning this competition against the Hughes OH-6A Cayuse.

The significant military competitions are discussed in more detail in Chapter VII. The impact of the newly emerging programs (the JVX and the LHX) are addressed in Chapters VII and IX.

C. CIVIL DEVELOPMENT

1. The Autogiros

The practical applications of the helicopter in the civil sector were in fact explored well before Sikorsky demonstrated his famous VS-300 in the late 1930s. Juan de la Cierva had brought the autogiro to the world, and in 1928, became the first pilot to cross the English Channel by autogiro. La Cierva's factory in England produced 90 autogiros but could not meet world demand and in the late 1920s, he granted production licenses around the world. Amongst these, Harold Pitcairn brought the autogiro to the United States. [5:61]

In 1932 Pitcairn was convinced that he could convert public enthusiasm into sales for the autogiro. His slogan, "this year own and enjoy a Pitcairn Autogiro", demonstrated his belief that he had purchased the U.S. rights to the "model T of the air" [5:62]. During the 1930s, his autogiro was put to many practical uses. The New Jersey State Forest Service used an autogiro to fight fires, business corporations flew them in promotional efforts, the Detroit News and the Des Moines Register and Tribune each had one t cover special stories, and they were used for archeological surveys and cropdusting.

After design improvements in the mid 1930s, the autogiro conducted trial takeoffs from a downtown Philadelphia post office roof and the United States Department of Commerce

authorized the development of a "roadable autogiro". The dream was that the autogiro would solve traffic jams, strengthen the national defense, and re-invigorate business [5:66].

Economic conditions prevailed, however, and buyers (among them Eastern Airlines, which used the craft on some of its mail runs), could not afford the increase in operating costs over conventional craft. The craft did not succeed as a product line but it did make a significant contribution to the development of the helicopter and had demonstrated the range of future helicopter applications prior to the initial flight of the first practical helicopter in the late 1930s.

2. The Helicopters

Civil applications of the helicopter were slow to develop. One of the earliest cargo lift demonstrations was conducted in Europe by Heinrich Focke, in December, 1940, when he transported an external load of 1284 kilograms a distance of 2 meters. In June, 1943, he conducted a similar experiment in front of Adolph Hitler, leading to a production order of 1000 (at a rate of 400 per month). Production was only in the early stages (nine completed) when World War II ended, disrupting any further production.

In the United States, early helicopter production was dominated by the military requirements of the U.S. Army Air Corps, prompted by an awareness that the helicopter

could be useful in war. Igor Sikorsky, however, had humanitarian visions of the helicopter:

> I could see helicopters carrying people and goods directly to the destination, and not 10 to 15 miles away and then transported there by other means. I also foresaw the helicopters unparalleled ability as a rescue device under the greatest variety of circumstances. [9:15]

In spite of this, history has shown that although virtually every helicopter designer has stressed the rescue role, it is the military potential of the helicopter that has paid for the technological development of the industry. [9:15]

Some years earlier, the Army, in a report on the first U.S. military helicopter development contract (the de Bothezat helicopter, first flown in 1922), was critical of the complexity and poor performance of the helicopter, stating that;

> These features are such as to rule out its development except in the case of such military urgency that the life of the pilot and the observer is of little consequence....the future development of the helicopter proper appears to rest rather in the single screw type, and the reasons for this are at least strong enough to warrant the building and testing of such a type before multiple screw types are adopted. [9:19]

Thus the military was attempting to impose its requirements in the very early stages of industry development.

After World War II ended, helicopters developed by Sikorsky (the S-51 and the S-52), Bell (the Model 47), Hiller (the Hiller 360), and Kaman (the K-190) all achieved civil certification by April 15, 1949. The noteworthy

feature of these events was the fact that none of these manufacturers were certain of their civil markets. More importantly, the potential buyers were not aware of the possible range of uses and had to be convinced by the manufacturers.

Tug Gustafson was the first Sikorsky helicopter salesman. When World War II ended, Sikorsky had to decide whether they would build commercial helicopters. Gustafson was sent to Washington, where the uninformed Departments of Agriculture and Forestry advised that if the helicopters could be built, the Forest Service would buy 500 and the Department of Agriculture would buy 200. Sikorsky, believing that the helicopter could be sold by the thousands, decided to build the commercial S-51 with a planned production of 60 for the first year, at a price of $48,500. First year sales were only 11, falling to three in the second year. Gustafson later said,

> We had a helicopter....but we did not know what to use it for. Where we thought that 95 percent of the problems were going to be technical, that marketing them would be simple, we really found out in the first two years that the problem was that there was no market, even though the machine was ready to fly. So the first thing we had to do was to go out and find and develop possible applications. [7:164]

In 1947, Gustafson opened the first shuttles in Boston, which lasted four months before going bankrupt. In the fourth year of production, Sikorsky was selling very few commercial helicopters and they concentrated on the military

market. The Korean War developed the Marine Corps interest in helicopter combat assault and Sikorsky pursued that market, leading them to develop a line of progressively heavier and more capable helicopters, primarily for the military requirements. [7:164]

Bell Helicopters encountered similar difficulties. After developing the Model 47 light helicopter and achieving the first civil certification in the world in 1946, the President of Bell, Larry Bell, stated to his test pilot, Joe Mashman,

> Now we have got to try and sell the helicopter, Joe. I want you to go out and demonstrate that machine. [7:161]

Initial demonstrations were to the U.S. military, but in 1947, the Argentine government decided to buy some helicopters to fight locusts. During a year long program, Mashman operated 12 Model 47s in Argentina and demonstrated them all over Latin America. Mashman later stated,

> Right from the start, you found that you demonstrated to people that didn't believe in helicopters....especially in the 1950s and 1960s, the civil and military markets were first learning about helicopters. [7:162]

Tug Gustafson joined Bell in 1948, when Bell was struggling, and trying to develop a commercial business. They formed a company called Bell Aircraft Supply, with four helicopters, four pilots, four mechanics, $250,000, and a charter to "go find the market" [7:164]. They determined that the agricultural market was promising, and that the

helicopter was the ideal applicator. However, the agricultural program was a disappointment and Bell looked for another market, following a directive from the Board of Directors that they had "90 to 120 days to satisfy the Board that we should keep the industry alive" [7:166]. So Gustafson approached the petroleum industry searching for oil in the swamps of Louisiana and won enough contracts to satisfy the Board. The market he had developed was oil exploration support, gravity surveys, and seismic surveys.

Having developed the market, Bell sold Bell Aircraft Supply for $100,000 in February, 1949. This new company eventually became Petroleum Helicopter Inc. (PHI), today one of the biggest commercial helicopter operators in the world. [7:166]

Hiller, being one of the few companies formed solely to build helicopters, and without corporate financial support, was struggling to keep alive in 1948, when civil certification for the Hiller 360 light helicopter was obtained. Hiller stated,

> When we started production, we didn't know what the market was; we thought it was agriculture, we installed some agricultural equipment; we thought it was rescue, we installed some rescuing equipment. But the customers didn't know how to use them. It was a very dark period in our existence because we had put all this money and effort into a vehicle and we had certified it, we had started production but we had no customers. [7:175]

At this point, a dramatic high altitude rescue in Yosemite by a Hiller 360 (following the failure by Bell and

Sikorsky helicopters to complete the rescue) attracted world-wide attention and led to civil orders for the Hiller 360 rescue helicopters, some deliveries to the French for use in Indochina, orders from the U.S. Army, and survival of the company through this period.

Kaman never really attempted to penetrate the civil market, despite obtaining civil certification for his helicopters in the late 1940s, primarily for cropdusting applications. The Kaman helicopters were designed especially for the Navy and did not really answer commercial needs. Kaman's test pilot, Bill Murray, stated,

> ...we never built an aircraft intended for the commercial market at the beginning. [7:185]

Thus, by the early 1950s, the major manufacturers had all attempted, in some way, to sell civil helicopters. The anticipated explosive growth of commercial applications had not eventuated, with potential buyers requiring substantial demonstrations to be convinced. Despite the apparent possibilities, the helicopter was constrained by a lack of power, and consequently, a lack of useful payload, and by a disbelieving and unconvinced marketplace.

Even after the Korean War, all commercial helicopters were direct adaptations of military types, and the helicopter design of the 1960s was commensurate with the fixed wing state of design art of the 1930s. The combination of military hardware and immature design was not a good

formula for commercial success, so the growth of commercial use was very shallow for twenty years. In commercial terms, this slow growth can be attributed to the high capital cost of helicopters, high operating costs (caused by high maintenance requirements), poor payload capability, lack of public awareness of helicopter capabilities, and the lack of all weather flight capability. [10:2]

The Vietnam war, with the vast deployment of helicopters, stimulated a boost in military helicopter technology that was able to be transferred to the commercial sector. The most significant development was the introduction of the turbine engine into the light, 4/5 seat helicopter that opened up a new era in commercial helicoptering. The major beneficiaries of these developments were Bell and Hughes, who had decided to concentrate on this sector of the market, with a philosophy of building helicopters that commercial operators could make money with. Sikorsky and Boeing-Vertol were concentrating on the heavy end of the market. Whilst they did achieve sales in those sectors that required heavier lift and longer range, their helicopters were generally too expensive to buy and operate for the small commercial operator, owing to their very specialized military origins. Additionally, the hoped for airline usage has never developed, primarily because the helicopter cannot compete with a comparable-capacity conventional fixed wing aircraft on the basis of seat/mile costs, the bottom line for an air carrier.

Bell and Hughes were both able to take advantage of military developments to transfer technology to commercial derivatives and to expand the market for many applications of the light turbine-powered helicopter.

Recent development has concentrated on increasing visual appeal, reducing vibration levels, increasing passenger comfort, reducing maintenance requirements, and offering wide ranges of optional kits to make the helicopter easily adaptable to a wide range of applications.

Bell and Hughes have both targeted corporate/executive use, emergency medical service/air ambulance markets, media news gathering roles, agricultural and forestry use, and many public service applications. The helicopter has found a market in the construction and logging industries, and it is in this application that the heavy lift helicopters of Sikorsky and Boeing-Vertol have found some sales.

During the 1970s, the booming civil market was the off-shore oil rig support market. Demand for helicopters in this role is closely correlated with the state of the oil industry and declined in 1980/81. All U.S. makers attacked this market, Bell and Hughes looking at the short-haul market, and Sikorsky and Boeing-Vertol hoping for sales in the long-haul crew change market.

The strength of the commercial market in the 1970s led to the development of the only two U.S. helicopters designed especially for commercial use, the Bell 222 and

the Sikorsky S-76. Boeing-Vertol also developed a commercial version of the Chinook, the Boeing 234. Sales of all three have not been outstanding, due mainly to the falling market caused by the recession and high interest rates of the late 1970s and early 1980s.

The most significant recent occurrence has been the development of the twin turbine light helicopter, which has increased customer confidence through increased safety margins and has increased the payload to empty weight ratio and expanding the range of applications.

Paralleling this airframe and engine development has been the technological advances in helicopter avionic systems, leading to a much improved all weather capability and further expansion of existing markets. [10:4]

The growth of the civil market can be seen by reference to Figure B-4. The growth has been quite dramatic in the last five years, with the corporate/executive market being dominant, largely due to the advent of the improved light turbine helicopters being offered by Bell and Hughes, and the more recent advent of the light twin helicopter. The disturbing factor for the U.S. helicopter industry, however, is the increasing European presence, as indicated by Figure B-9. This issue is addressed in more detail in the concluding section of this chapter.

D. SIZE AND COMPOSITION OF THE U.S. HELICOPTER INDUSTRY

There are a number of difficulties associated with estimating the size and composition of the U.S. helicopter industry. There are numerous sources of data, and results from different sources are not always comparable owing to different methods of measurement. Most data sources publish units produced. In terms of sales volume this can be misleading, e.g., Bell and Hughes produce large numbers of small, relatively cheap helicopters, whilst Sikorsky and Boeing-Vertol produce fewer numbers of more expensive helicopters. Information is not always timely and is frequently revised several years after the event. Aggregate data is relatively easy to obtain, but companies are very sensitive about releasing business segment data, particularly data revealing financial performance.

The analysis that follows is designed to indicate relative trends only and does not purport to provide absolute measures of performance. Numbers have frequently been rounded to make the trend more easily apparent without destroying the credibility of the data.

The data for Tables A-1, 2, A-2, A-3, A-4, A-5, and A-8 were extracted from the internal records of one of the major U.S. helicopter manufacturers and represent an aggregation of data of all of the world helicopter manufacturers.

Free world helicopter production, in units of production annually, is shown in Figure B-1 (data from Table A-1). The

graph clearly indicates the general rising volume for the period 1943 to 1980. The peaks in 1953 and 1968 were caused by the Korean and Vietnam conflicts. The dramatic effect of the Vietnam era is quite apparent. Soviet helicopter production is not included in this data. Whilst good, reliable Soviet data is not available, it has been estimated by one of the U.S. manufacturers that the change in production shares from 1970 to 1980 is as shown in Table 1 below.

TABLE 1

CHANGE IN WORLD PRODUCTION SHARES 1970-1980

	1970 (Percent)	1980 (Percent)
UNITED STATES	65	40
WESTERN EUROPE	15	17
USSR/EAST EUROPE	16	39
OTHER	4	4
TOTAL PRODUCTION-(UNITS)	3717	3800

These figures indicate a relatively pronounced increase in Soviet market share. Since the Soviet expansion has been mainly in heavy helicopters, the Soviet intrusion is greater in terms of pounds of production, but does not have a great effect on the light and intermediate world helicopter markets.

Annual unit production for the U.S. manufacturers is shown in Figure B-2 (Table A-2) and Figure B-3 (Table A-3). Bell helicopter has dominated production (in units) for all three peaks in 1952/53, 1968, and 1980. Hughes also contributed to the Vietnam peak with production of the OH-6A Cayuse light observation helicopter.

The U.S. makers market shares of the total free world helicopter production are shown in Table A-4. The data have been rounded to the nearest percentage point. Selected data are presented for ease of reading and the peak years' data are included. The very apparent trend is the declining market share of Bell, resulting in the declining U.S. market share. In 1982, foreign makers produced more than the U.S. makers for the first time. The Sikorsky share is increasing as a result of the production of the UH-60 Black Hawk.

Similar data for the European makers is shown in Table A-5. Again, the data have been rounded. Two trends are apparent, firstly the increase in the European market share over the last decade from about 30 percent to just over 50 percent, and, secondly and perhaps more significantly, the increase in the market share of Aerospatiale of France to over 20 percent of total free world production.

U.S. helicopter production is shown in Figure B-4 (Table A-6). The data shown in this figure varies from the data in Figure B-2, due in part to the different data source, and in part to the fact that it does not include foreign

military sales. What is significant, however, is the general trend indicating the vast production to support Vietnam in the mid 1960s, followed by a declining military production and an increasing civil percentage. Also apparent is the declining civil sales in 1981/82, due primarily to poor economic conditions.

U.S. helicopter production in dollars is shown in Figure B-5 (Table A-7). The correlation between Figure B-5 and Figure B-6 is good up until 1979. At this point, the dollar value of military deliveries increases despite a declining military unit production, reflecting the military requirement for a fewer number of more sophisticated and hence more expensive helicopters.

The U.S. manufacturers percentage of U.S. production is indicated in Figure B-6 in cumulative form (the data are presented in Table A-8 in absolute form). The early dominance of Sikorsky is apparent, with Bell rapidly gaining market share in the 1950s. Boeing-Vertol's contribution to the Korean conflict in the 1950s can be seen. The dominance of Bell and the emergence of Hughes in the mid 1960s Vietnam period is also apparent. In the early 1980s, Sikorsky, Hughes and Bell have emerged as the major forces in terms of unit production U.S. market share

Figures B-7 and B-8 (Tables A-9 and A-10) indicate the relative movements of U.S. imports and exports. The graphs show the general decline in civil helicopter sales in 1981

and 1982 (the 1983 and 1984 figures are estimates and forecasts respectively).

The data in Figures B-9 and B-10 (Tables A-11 and A-12) reveal the fact that Aerospatiale has the largest share of foreign imports. Europe now accounts for 50 percent of the free world production and Aerospatiale constitutes some 40 percent of that European market presence (Table A-6).

Figure B-11 (Table A-13) indicates that whilst all segments of the civil helicopter market have shown steady growth since the 1960s, the dominant growth segment has been the commercial helicopter. A contributing factor to this growth has been the boom in off-shore oil rig support, air ambulance, air taxi, news media gathering, and corporate/ executive transport.

E. THE GROWTH OF THE EUROPEAN THREAT TO U.S. MARKETS

This chapter would not be complete without a discussion of the European intrusion into the U.S. civil market. Figure B-9 shows the growth of European helicopters imported into the United States. The degree of penetration by Aerospatiale of France has the most significance. This section will consider the growth of Aerospatiale.

In the period 1940-1945, the Focke-Achgelis Company in Northern Germany successfully produced helicopters but production was halted by the cessation of World War II. Other European efforts in Austria, Germany, France, and England

were similarly disbanded in 1945. Beginning in 1945, the French and English governments decided to promote new helicopter concepts. The French Government allocated funds to the principal French aeronautical companies to design and build rotary wing aircraft. In the period 1945 to 1952 the Societe Nationale de Construction Aeronautique du Sud-Est (SNCASE) evaluated the Focke-Achgelis technique, whilst the Societe Nationale de Construction Aeronautique du Sud-Ouest (SNCASO) became interested in the Doblhoff tip-jet technique. The Societe Nationale de Construction Aeronautique du Centre (SNCAC), the Bregeut Company, the Societe Nationale de Construction Aeronautique du Nord (SNCAN), and the Societe Nationale de Construction du Sud-Est (SNCASE) all produced helicopters that flew during 1948, 1949, and 1950, but none passed through the testing stage. The results were disconcerting and the SNCAC, Bregeut, and the SNCAN companies decided to halt expenditures and abandon helicopters. In 1950, only SNCASE and SNCASO remained competitive (in France) to try and find more suitable techniques. [1:150]

In Britain, after some attention to autogiros, the Bristol Aeroplane Company produced the first functional European production helicopter, the Bristol Sycamore, of which 200 units were produced. The Westland Company became involved in building Sikorsky helicopters under license (first the S-51, then the S-55), before joining forces in 1959/60 with the rotary wing activities of the English firms,

Saunders-Roe, Bristol, and Fairey. SNCASE, prompted by events in Algeria, acquired a license for the Sikorsky S-55 in 1952 and the Sikorsky S-58 in 1956. Sales and maintenance contracts were signed by other French firms for Bell, Hiller, and Piasecki aircraft, as the Europeans recognized that the American products, being 5 to 10 years more advanced than the European technology, were dominating the market. They were joined by the Italian firm, Agusta, who bought a license for the Bell 47 in 1952. [1:151]

The period 1952-1959 marked the turning point of the European industry and saw the arrival of turbine helicopters, in a sequence of events that favoured the French industry, leading to that nation's dominance of the European makers.

Of the two main French firms, SNCASO moved towards tip jet helicopters, whilst SNCASE developed a Sikorsky type single main rotor helicopter. The design teams of the two firms were given the objective of producing light helicopters weighing less than 800 kilograms empty. The SNCASO approach led to the Djinn, which received French certification in 1957 and American certification in 1958. As mechanically driven helicopters improved, the advantages of the Djinn diminished, and it never achieved great success. In the meantime, SNCASE developed the three-seat piston engined Alouette I, which first flew in 1951. In 1953, it was decided to mass produce this helicopter but the advent of the turbine engine reversed this decision. In order to

achieve market success, it was decided to develop a new helicopter that would be competitive but superior in performance to existing light helicopters. It would be a five place helicopter, designed around the advantages of a turbine engine, and basic in design and uncomplicated (making it capable of being disassembled into sub-units to facilitate production, maintenance, and sales). These requirements led to the Alouette II that was first produced in 1956. Previously, the American firms of Kaman, Bell, and Sikorsky had all experimented with turbine power beginning in 1951, but they had only limited success. The secret of the success of the Alouette II lay in its sound design and ease of construction leading to decisive advantages in performance, safety, and maintenance [1:156]. This helicopter received French certification in 1957 and American certification in 1958. By the end of 1959, more than 300 Alouette II helicopters had been produced [3:157]. Total production through 1975 (the end of production) was 1307 units.

In 1957, SNCASO and SNCASE merged to become Sud-Aviation. This firm adopted a philosophy of continuous innovation and incremental improvement in order to improve the commercial position of the French industry. This approach has proved very successful, as reference to Figure B-12 will reveal. The graphs indicate sales, employment, and product introduction history for Aerospatiale. The planned expansion was emphasized by a new prototype every two or three years. [7:250]

The Alouette II was rapidly followed by the Alouette III which first flew in March, 1959. With seven seats, it had no competition. A further innovation was the use of a strongly "derated" engine (i.e., used below maximum power). This meant that the helicopter still had a lot of power available at maximum throttle at high altitude. Further, it was readily adaptable for rescue operations and ambulance operations [7:251]. The superiority of the Alouette III was demonstrated when the first French military orders were awarded to the company. Production amounted to almost 1400 units and continued until 1979 in France and 1981 in India and Romania (licensed production). Several product improvements were introduced during the life of the model.

In 1969, the company merged with Nord-Aviation, to become the Societe Nationale Industrielle Aerospatiale (or Aerospatiale). This year also marked the commencement of the first real intrusion into the American market, with the creation of Vought Helicopter Incorporated (VHI) by Ling-Temco-Vought, who desired to become a new helicopter manufacturer. They held production licenses for the light Alouette and Gazelle helicopters. These aircraft were successful and led to Aerospatiale buying the helicopter subsidiary from Ling-Temco-Vought and renaming it the Aerospatiale Helicopter Corporation (AHC). The acquisition included the entire staff and was able to capitalize on the tremendous early promotional work of the Alouette and Gazelle.

Today, the AHC is located in modern facilities in Grand Prairie, Texas. Deliveries in 1980 represented 20 percent of the North American commercial market. [7:249]

The Alouette III was rapidly followed by the Frelon (a three turbine naval helicopter) in 1959, the Super Frelon (a thirty place three turbine upgrade of the Frelon) in 1962, the SA-330 Puma (a French Army tactical helicopter that subsequently enjoyed considerable commercial success in Europe), the SA-340 (a high performance, five place, light helicopter that employed newly developed fibreglass blades) in 1968, and the SA-315 Lama in 1968. This was a combination of the light Alouette II airframe and the rotary parts of the more powerful Alouette III, especially designed for high altitude work and still remaining without real competition in this field.

The philosophy of modernization and improvement was further applied in the 1970s with the development of the AS-360 Dauphin (a modern Alouette III with increased performance and safety, decreased maintenance, and with ten seats). Aerospatiale recognized the market tendency towards twin engined safety, and upgraded the Dauphin to the AS-365C, for which commercial certification was received in 1978. A further model improvement led to a successful bid in a U.S. Coast Guard contract to modernize their fleet in 1979.

The Gazelle had been a successful military helicopter but its high performance made it relatively expensive, and

therefore, not competitive in the commercial field. Accordingly, Aerospatiale set about designing a new six seat light turbine helicopter with two prime objectives, reduction of production cost and reduction of operating cost [7:255]. The consequent AS-350 Ecureuil was produced in two versions, one for the European market (with a Turbomeca engine), and the AStar (specifically designed for the North American market (with the Lycoming LTS 101 American turbine).

Aerospatiale entered the medium weight market in 1981 with the upgraded and stretched AS-332 Super Puma, aimed at the emerging long distance off-shore oil rig support market [7:252].

As they had for the Dauphin, the engineers returned to the single engined Ecureuil AStar to transform it into a twin turbine craft. The AS-335 TwinStar first flew in 1979. A further upgrade of the TwinStar was certified in America in 1981. The TwinStar has proved most popular in the corporate and emergency medical services (EMS) markets, with eleven being employed in an EMS role by the end of 1983 [11:34]. This aircraft competes with the MBB Bo-105 and the Agusta 109 in the North American light twin market. Bell is preparing a new model 400 TwinRanger, which will be made in Canada and which is heralded as the first in a new line of Bell single and twin light helicopters designed to combat the French invasion.

Leaving aside the Gazelle and the Lama, all the other Aerospatiale helicopters are very modern and constitute a very aggressive entry into the world and U.S. markets. Without counting aircraft manufactured under license, Aerospatiale Helicopter Division had sold (by the end of 1981), almost 7000 helicopters of all types to 520 customers spread over 100 countries [7:256]. Reference to Figure B-9 quite clearly indicates the very successful results Aerospatiale has achieved in the North American market in the last five years.

Despite the fact that Aerospatiale is the primary contributor to the European penetration of the U.S. market, the potential impact of the other European makers should not be minimized. MBB has two subsidiaries in North America and has become the first European manufacturer to plan production operations in North America, with its announced intention of producing the MBB Bo-105 in Canada for distribution through its MBB Helicopter Corporation (MBBHC) subsidiary in West Chester, Pennsylvania.

Agusta has also targeted the North American corporate and public service markets with the Agusta 109 light twin eight place helicopter.

Westland Helicopter, of England, has aimed a development of the successful military Lynx series, the Westland 30, at the American market (commuter, ambulance, off-shore, executive, and cargo roles), with three helicopters being in

interline airline service in Los Angeles and two in New York. They are also developing the EH-101 (for military and civil markets), in collaboration with Agusta of Italy.

In summary, the European helicopter industry emerged after World War II. The European companies had experimented on their own, and all had contact with American manufacturers in one way or another, ranging from design help to outright purchases of licenses to manufacture. Once begun, progress in the European helicopter industry was rapid. Today, according to the Aerospace Industries Association of America's November, 1983 report, "The U.S. Helicopter Industry", European manufacturers account for over 50 percent of free world production, and Aerospatiale accounts for about half of that share. Many helicopters, American or foreign, have both military and civil versions. While it appears that the military/civil divergence is increasing, some of the newest European designs are conceived with both civil and military applications in mind. [12:71]

IV. COMPETITORS IN THE HELICOPTER INDUSTRY

A. INTRODUCTION

In its approximately forty year history, the helicopter industry has spawned many participants. The successful firms have generally survived through a combination of fortuitous good luck and winning the right military competitions, although in some cases, a firm has achieved great success with a product line or concept after losing the contest it was entered in. The survivors, at least those who dominate the market, have one factor in common; they are all part of a larger corporate or national organization.

The American participants have produced over two-thirds of the free-world's helicopters over the last twenty years. They are: Bell Helicopter Textron Inc., a subsidiary of Textron Inc.; Boeing-Vertol Company, a division of the Boeing Company; Hughes Helicopters Inc., a subsidiary of the McDonnell Douglas Corporation; and Sikorsky Aircraft, a division of United Technologies Corporation. Other U.S. manufacturers include Hynes Helicopters Inc., the Enstrom Corporation, Hiller Aviation Inc. (recently acquired by Rogerson Helicopters after running into financial difficulties), the Kaman Corporation, and Robinson Helicopter Company Inc.

The balance of the free-world's helicopters have been mainly manufactured by the four major European makers, namely:

Societe Nationale Industrielle Aerospatiale of France; Messerschmit-Boelkow-Blohm (MBB) of West Germany; the Agusta Group of Italy; and Westland Helicopters of the United Kingdom.

There are also several foreign makers who are predominately involved in licensed production of helicopters designed by one of the eight major manufacturers. These firms include Nurtanio of Indonesia, Helibras of Brazil, and Kawasaki, Fuji and Mitsubishi of Japan.

The European and foreign firms, in general, gained their entry to the industry through licensed production of U.S. designs, buying design, manufacturing, production, and technical expertise.

This chapter will provide a brief profile of each of the major competitors, as well as some comment on the minor manufacturers, Soviet producers, and some competitors who failed.

B. U.S. COMPETITORS

1. Sikorsky Aircraft

Igor Sikorsky is considered by many to be the father of the helicopter industry. He initially experimented, unsuccessfully, with helicopter designs in his native Russia in 1909 and 1910. He was constrained by the lack of a suitable propulsion unit and surrendered his interest in helicopters for a number of years. He came to America following the

Communist Revolution in Russia in 1917 and founded his own company, successfully producing fixed wing aircraft for a number of years. In 1929, the financially troubled Sikorsky Aviation Corporation became first a subsidiary of and then a division of United Aircraft, now the United Technologies Corporation.

In 1938, after 10 years of research, he received the go-ahead to proceed with the design and construction of a direct lift aircraft. The subsequent first flight of the VS-300 on September 14, 1939, marked the birth of the helicopter industry. By 1941, Sikorsky aircraft were in service with Army and Naval Air Forces around the world. No other U.S. manufacturers then existed.

His early designs established the Sikorsky design preference for a single main rotor/single tail rotor concept and a penchant for a "bigger is better" philosophy. An examination of the Sikorsky product line development over the years will reveal that these philosophies have remained with Sikorsky.

As with most helicopter manufacturers, Sikorsky has approached commercial helicopter design by adapting designs developed under military contracts. Following World War II, Sikorsky developed helicopters aimed at both the military and civil markets. These included the S-51, a derivative of the early military VS-327 (military designation R-5), which achieved quantity production of about 380 units in the late

1940s,/early 1950s, and the S-55 (military designation H-19), the first troop carrier, which achieved a production run of approximately 1800 units through the 1950s, and the S-58 (military designation H-34) that reached a production total of over 2200 units.

The late 1950s saw Sikorsky take advantage of the available technology, and they entered the turbine powered helicopter field with the S-61 (SH-3), S-64 (CH-54A/B) and S-65 (CH53A/D). These aircraft became progressively larger as Sikorsky gained more design and production experience. Over 1600 of these aircraft were built during the 1960s and they saw service in a wide variety of civil and military roles. The S-61 remains in military service in substantial numbers around the world and its civil variants were and still are highly successful in the emerging civil market at that time; i.e., off-shore oil rig support.

In the early 1970s, Sikorsky went through some difficult times as their long running production lines began to dry up, without the arrival of new production programs. Sikorsky applied considerable company effort to winning the Army Utility Tactical Transport Aircraft System (UTTAS) competition with its Black Hawk entry. The program was won in 1976 and has led to successful access to other military derivative programs (Navy Seahawk and Air Force Night Hawk). It also provided opportunity to develop a commercial derivative and an overseas military version for foreign military sales.

The successful S-65 program has also led to success in the Navy and Marine Corps requirement for heavy-lift helicopters with the triple turbined, 70,000 lb. CH-53E Super Stallion, now the free world's largest helicopter.

Also in the 1970s, Sikorsky broke with tradition and developed the S-76 purely for the commercial market (primarily for the corporate, executive and oil rig support market). This aircraft was sized between its perceived competition, the Bell range of light helicopters and the medium-lift helicopters produced by Boeing-Vertol. This helicopter has not been as successful as Sikorsky would have liked, due in part to the general decline in civil helicopter sales in the early 1980s.

Sikorsky has licensed Agusta, Westland, and Mitsubishi for overseas production of U.S. designs. In history up to September 14, 1979, Sikorsky had produced a total of 5545 helicopters, with an additional 1672 units being produced by foreign licensees.

Sikorsky has always been actively involved in ongoing research and development, devoting considerable effort to the Advancing Blade Concept (ABC), believing it to be the answer to developing high speed requirements. Other endeavors include the Advanced Composite Airframe Program (ACAP), an Army funded program to develop a lighter all composite airframe, and the Sikorsky-developed Rotor Systems Research Aircraft (RSRA), a joint NASA/Army program to develop new technology rotor systems.

In terms of new military programs, Sikorsky will be an entrant in the major new helicopter program, the Army new Light Helicopter (LHX) program that promises substantial production orders through the year 2000. Sikorsky sees this program as a successor to the Black Hawk program in terms of keeping its production shop floor busy.

2. Bell Helicopter Textron Inc.

Larry Bell launched the Bell Aircraft Corporation on July 10, 1935, with 56 employees. His company achieved success in the war years, producing many fighters and bombers for the war effort. By 1944, the company employed more than 50,000 people in four plants.

At the beginning of the war, Bell had hired Arthur Young, an inventive engineer who was very interested in helicopters. Young and his small staff were established in a small garage in Buffalo, completely divorced from the war efforts of the company. The Bell helicopter wasn't quite ready at the end of the war but in September, 1945, Bell announced that his company would enter the helicopter field. His foresight paid off because after V-J day in August 1945, almost all the company's business was cancelled. Bell's business base dropped from $317 million in 1944 to $11 million in 1946 and the workforce dropped to 2920.

Bell was confident of his helicopter development, and, anticipating significant military and commercial applications, decided to build 500 units without orders. Commercial

sales were slow, however, and it appeared that Bell might have made a mistake. In the period to 1950, Bell only sold 175 helicopters. The Korean War intervened, however, and the Army urgently required a large number of helicopters. The advanced Sikorsky S-52 was not in a production-ready stage, and Bell was able to win the competition on delivery schedule with its now famous Bell 47 production line. This win put Bell on the map, with the Bell 47 being phased out of production in 1974 after a cumulative production run of 6263 units, with about fifty percent of these going to military customers.

The next major event for Bell was the winning of a design competition for the development of a utility helicopter suitable for medevac, general utility and training purposes. Bell won this competition in 1959 with the ubiquitous UH-1 "Huey", the first production beneficiary of the newly developed gas turbine engine. This win led to a production run of over 12,000 units of the various derivatives, marketed as the UH-1 (military) and the Models 204, 205, 212, 214 and 412 (civil).

In 1962, the U.S. Army's Tactical Mobility Requirements Board issued a report that officially endorsed, for the first time, the use of armed helicopters. The war in Vietnam demonstrated this truth, and the armed UH-1 Huey was pressed into service as an interim measure. Bell was initially eliminated from the requirements design competition in early

1965, but with a private-venture development of the Bell 209 was able to win the subsequent production competition. That aircraft was born as the AH-1G Cobra. It also enjoyed a very long production run of 1775 units and will remain in service (product improved) until the year 2000.

Bell's business in recent times has been less promising. Whilst continuing to enjoy civil success with their light derivatives, Bell entered and lost a number of military competitions that provided good opportunities for competitors to steal some of Bell's military business. These were the Army Light Observation Helicopter (LOH) competition in 1961, lost to the Hughes OH-6 (subsequently the very successful Hughes civil 5-0); the Army Advanced Attack Helicopter (AAH) in 1973-76 to the Hughes AH-64 Apache; and the Army Utility Tactical Transport Aircraft System (UTTAS) to replace Bell's Huey in 1976 to the Sikorsky UH-60 Black Hawk.

These were significant losses to Bell, who is now under considerable pressure for continued survival to win either or both of the two major current military programs, the Joint Services Vertical Lift Aircraft (JVX), and the Army's Light Helicopter Program (LHX). Bell has been kept alive in the military business by winning the recent Army Helicopter Improvement Program (AHIP) against Hughes to develop a near term scout helicopter. Bell was also selected as one of two winners (with Sikorsky) to participate in the Advanced Composite Airframe Program (ACAP).

Perhaps Bell's most promising military work is its teaming arrangement with Boeing-Vertol to participate in the development of the JVX. Whilst the team is the only one under contract for the development phase, it appears that the government intention is to compete the two firms head to head for follow-on production after initial production. Bell has a head start in this program, having developed its tilt-wing technology in an earlier (1951) Army-Air Force Program that funded the development of the experimental XV-3 tilt-wing convertiplane in 1955. This led to the XV-15 occurring in 1977 (under joint Army/NASA sponsorship).

Bell Helicopter has licensing arrangements with Agusta of Italy; Mitsui of Japan and Nurtanio of Indonesia.

Bell Helicopter Corporation was founded as a wholly owned subsidiary of the Bell Aircraft Corporation in 1957. On July 5, 1960, Textron Inc. purchased the defense activities of Bell Aircraft Corporation, setting up Bell Aerospace Corporation as a wholly-owned subsidiary with three operating divisions, the Bell Helicopter Company, Bell Aerosystems Company, and the Hydraulic Research and Manufacturing Company. Bell established itself as Textron's largest division and in January, 1982, the company status was changed to Bell Helicopter Textron Inc., a wholly owned subsidiary of Textron Inc.

Bell's philosophy throughout the years has been to build helicopters for the light and intermediate market segments, relying primarily on military aircraft with civil

adaptability. A significant effort has been applied to developing civil derivatives that can be competitive regarding price and operating costs, i.e., to build aircraft that operators can make money with.

Bell, like Sikorsky, has recently developed a pure commercial model, the Bell 222, also for the corporate, executive and oil market. It is somewhat smaller than the Sikorsky S-76, but its sales have not been impressive, again due in part to the declining civil market in the early 1980s.

One of Bell's early competitive advantages was its extremely simple and inexpensive two-bladed see-saw rotor systems that helped to keep price and operating costs down. It would appear that Bell was reluctant to progress from this technology even though their customers wanted the extra advantages of a four-bladed articulated rotor system. This reluctance prevented them from capturing market share that they might otherwise have obtained.

3. Boeing-Vertol

P-V Engineering Forum Corporation was incorporated by Frank Piasecki in 1943. This organization designed and built the PV-2, which first flew on April 11, 1943. It was the second U.S. helicopter to be flown publicly. The company's second aircraft was the PV-3, the world's first practical tandem rotor machine that led to production of the "flying banana" (the Navy HRP-1) in 1947. This success was a result of a private-venture by Piasecki to build a demonstrator

(the XHRP-X) in 1945. In 1946 the company changed its name to the Piasecki Helicopter Corporation. The HRP-1 was improved to the HRP-2 which was sold to the Air Force and the Army as the H-21 (Workhorse and Shawnee).

This aircraft saw considerable service in Vietnam and was used by many foreign military forces. The original armed helicopter trials were carried out with the Shawnee but the concept never developed for Boeing-Vertol, the armed helicopter battle being won by Bell with its armed "Huey" and later the Cobra.

Piasecki also entered the Navy market in 1949 with its smaller PV-14/18 (HUP Retriever or H-25 Army Mule). This aircraft also had the traditional tandem rotor and had a production run of about 270, with some of the Navy aircraft being fitted with dipping sonar.

In 1950, Piasecki was contracted by the U.S. Air Force to develop a long range rescue helicopter. The subsequent helicopter, then the world's largest, was unsuccessful although the second of the two prototypes was credited with being the world's first twin engined turbine helicopter. The program was cancelled in 1954 after the crash of this prototype.

In 1956, Piasecki adopted the name Vertol, and Boeing Aircraft acquired Vertol in 1960 when it became the Vertol division of the Boeing Company.

Piasecki (or Vertol) conducted a private-venture into a high speed compound helicopter in 1962, resulting in some Army/Navy sponsorship for modifications to the 16H-1 Pathfinder to achieve a speed of 230 mph. It successfully flew at 225 mph but did not enter production.

Boeing-Vertol continued the tradition of tandem rotor design, developing the Model 107 as the H-46 for the Army as a medium lift transport. This aircraft achieved quantity production and entered service in 1962, serving with the Marine Corps and the U.S. Navy and has been licensed overseas to Kawasaki as the KV-107. Boeing-Vertol production was 666 machines when production ended in 1971.

The very successful Boeing-Vertol 114 (CH-47) followed, entering service in 1962 and becoming the western world's standard for medium lift helicopters. It is flown worldwide and continues to be modified and updated. This aircraft also saw service during Vietnam when four were modified as "heavy gunships", as another forerunner of the armed attack helicopter requirement.

The Boeing-Vertol YUH-61A competed against Sikorsky for the Army Utility Tactical Transport Aircraft System (UTTAS) program, losing the competition on 23 December, 1976. Boeing-Vertol then entered a modification of the YUH-61A in the Navy's LAMPS III competition against a Sikorsky modification of its UH-60B UTTAS winner and a Westland/Aerospatiale

modification of their Lynx. The paper competition was lost to the navalized Sikorsky SH-60B on September 1, 1977.

In November 1970, the U.S. Army requested industry proposals for a heavy lift helicopter (HLH) able to carry a load of 20 tons for a radius of 20 nautical miles. Boeing-Vertol was selected to develop the concept, and built the model 347 helicopter, based on their CH-47 design. The subsequent development contract was cancelled in October, 1974, when the program was experiencing high costs and when the Navy and Marine Corps decided to pursue the Sikorsky CH-53E for their heavy lift requirements.

The prototype was never completed, although recent events indicate a re-awakening of interest, with Boeing-Vertol being contracted to complete the development of the prototype as a demonstrator of the heavy lift concept.

Commercially, Boeing-Vertol entered the market initially with the Piasecki V-44 in 1956. This was replaced with the turbine powered Model 107 (the commercial CH-47) in 1958. The Boeing-Vertol Chinook (CH-47) that first entered service in 1962 and has sold over 1000 units worldwide was developed commercially as the Model 234 Chinook, primarily to service the long range oil rig market.

The bulk of Boeing-Vertol's current business is modification of the CH-47 Chinook fleet, although the company is working on research projects such as the heavy lift helicopter, the Army/NASA X-wing project, and the private-

venture high speed helicopter, the Model 360. They are also involved, as a team member, with Bell Helicopter, in the Navy/Marine Corps Joint Services Vertical Lift Aircraft program.

Boeing-Vertol has licensed Kawasaki of Japan for Model 107 production, Agusta of Italy for Chinook production and itself had a license to market the German MBB Bo-105 in Canada, Mexico and the United States until withdrawing from that arrangement in 1978. The rotor system for Boeing-Vertol's UTTAS candidate was adapted from the MBB Bo-105, in a unique Europe to United States licensed technology transfer.

4. Hughes Helicopters Inc.

Hughes Helicopters traces its origins to February 13, 1934, when Howard Hughes Jr. launched the Hughes Tool Company Aircraft Division. Howard Hughes had a passion for aviation and the aircraft division was essentially his hobby shop. At the end of the war, when nearly all military programs were cancelled, Hughes kept his California team busy making proposals for new aircraft and missiles.

In 1946, Kellet Aircraft of Philadelphia was involved in developing the XH-17, a derivative of a European jet powered rotor machine. The advantage of this concept was that no heavy transmission was needed, the rotor being driven by compressed air feeding kerosene burning nozzles at the rotor tips, much like a lawn sprinkler. This made it particularly attractive for very large heavy lift helicopters.

The XH-17 had a rotor diameter of 130 feet and was to be capable of lifting 40,000 lbs. gross weight.

By 1949, with design completed and fabrication started, Kellet was in financial difficulties. Hughes, ever on the lookout for new work and an aviation challenge, purchased the XH-17 project and moved it to the Hughes Aircraft Company plant at Culver City, California. The XH-17 first flew in October, 1952 and the flight test program ran for three years. Whilst the program added to Hughes technology base, the advent of the Korean War shifted the emphasis to large numbers of small helicopters rather than a few very large helicopters.

Hughes then bought the rights to the very simple design of a three bladed rotor system developed by a neighboring firm, the McCulloch Motor Corporation, and focused on the very light range of helicopters. By 1956, Hughes had developed the Hughes 269, designed as a light, two place commercial helicopter. This company program led to the very successful Hughes 300 commercial helicopter.

In mid 1964 the U.S. Army selected the Hughes 269A as the TH-55A Osage light training and utility helicopter. A total of 2738 units of this model were built, with nearly 800 being delivered to the Army as the TH-55A. Hughes has now licensed the Schweizer Aircraft Corporation to produce the Model 300.

In the early 1960s the U.S. Army held a design competition for a turbine powered light observation helicopter. Hughes won the competition with its OH-6A Cayuse against proposals from Bell and Hiller. The Cayuse entered service in 1966 and about 1450 units were produced for military service, the aircraft being extensively used in the Vietnam conflict. Simultaneously, Hughes developed a commercial derivative, the Model 500 that has also become an extremely successful entry into a wide range of civil applications. The product line, including military and civil derivatives, had sold some 3600 units by 1983.

The philosophy adopted by Hughes in both the Model 300 and Model 500 was to "simplicate and add lightness" and to design for ease of maintenance and reduced operating costs.

Hughes has developed both the 300 and 500 models as overseas military versions, using their position as the free world leader in medium calibre cannon production to advantage.

Through a long sequence of events, Hughes won the Army competition for the Advanced Attack Helicopter in 1976 in a fly-off between its AH-64 Apache and the Bell YAH-63. These events followed the failure of the Lockheed AH-56A Cheyenne in the Army's Advanced Aerial Fire Support System (AAFSS) program in 1972. This success has led to production contracts for the Apache.

As a result Hughes is in the process of moving its operations to Mesa, Arizona, where it has built a new plant. Hughes has now been acquired by the McDonnell Douglas Corporation as a wholly owned subsidiary. With the corporate strength of McDonnell Douglas, Hughes will become a formidable competitor in the Army Light Helicopter program (the LHX) with its unique no tail rotor concept (NOTAR).

C. EUROPEAN COMPETITORS

1. Aerospatiale Helicopter Corporation

After World War II, the French Air Ministry, observing that France was lagging behind the U.S. in helicopter development, signed several contracts for helicopter design with the following companies: SNCASE, SNCAN, SNCAC, SNCASO, and Breguet. However, at the beginning of 1954, no French helicopters were being produced, with helicopter requirements being satisfied by the imports of the Bell 47, Hiller 360, Piasecki HUP-2 and the Sikorsky S-55. The S-55 was being produced by SNCASE under license. The Air Ministry determined that, in order to establish a niche in the industry, it was necessary to develop a helicopter that would not clash head to head with the American products. This led to the turbine powered Alouette II which first flew in March, 1955. This aircraft broke the international altitude record and was especially suited to mountain work. As a five seater, it occupied the segment between the three seat Bell 47 and Hiller 360 helicopters and the ten seat Sikorsky S-55.

In January, 1957, SNCASO and SNCASE merged to become Sud-Aviation. Under Sud-Aviation, production shifted to the Alouette III in 1959 (especially designed as a seven seater for high altitude work). The Alouette product line was a commercial success.

The parent company of Aerospatiale Helicopter Division (AHD), Societe Nationale Industrielle Aerospatiale (SNIA), was formed in January, 1970, by a merger of three government-owned companies, Nord Aviation (fixed wing aircraft and tactical missiles), Sud-Aviation (fixed wing aircraft and helicopters), and SEREB (space engineering). Thus, Aerospatiale is and always has been owned by the French Government. Up until this time, Sud-Aviation had always concentrated on light helicopters. In order to penetrate the medium and heavy markets, Sud purchased Sikorsky technology, leading to the Puma (twin engined 8000 lb. tactical transport), and the Super Frelon (three engined 15,000 lb. antisubmarine, passenger and cargo helicopter). The Super Frelon is no longer in production but about 100 remain in a variety of civil and military uses. The Puma also stopped production in about 1980, but is still in wide use. It has led to the multi-purpose civil and military Super Puma now in use in fourteen countries. The Super Puma competes head to head with the Sikorsky UH-60 Black Hawk for troop transport contracts. Aerospatiale is unique in both Europe and the U.S.

in that it offers a range of light to heavy helicopters, in civil and military variants, in simultaneous production.

Aerospatiale formed an arrangement with Ling-Temco-Vought (LTV) in the United States in the early 1970s in order to market Aerospatiale helicopters in the U.S., Canada and Mexico. This arrangement was disastrous in the beginning, with the main deficiencies being product support and inadequate customer credit investigation. In about 1974, management changes were initiated, and the name was changed from Vought Helicopters Inc., (VHI), to Aerospatiale Helicopter Corporation (AHC). The need to develop customer confidence in product support was emphasized and the result has been a significant penetration of the U.S. market by AHC.

Aerospatiale has been a consistent investor in research and development, allocating about 9 percent of sales to innovative technologies, particularly in the use of composites.

Aerospatiale has a wide range of licensing arrangements, including India (Alouette III and Puma), Yugoslavia (Gazelle), U.K. (Gazelle, Puma and Lynx co-production), Indonesia (Puma and Super Puma), Brazil (Lama and Ecureuil), and China (SA-365N Dauphin 2).

2. Westland Helicopters Ltd.

The British company, Westland Aircraft Ltd., (now Westland plc), was formed in July, 1935, to take over the

aircraft branch of Petters Ltd., known previously as the Westland Aircraft Works, which had been engaged in aircraft design and construction since 1915. The Westland story is the familiar one of a traditional European aviation company moving into helicopters after World War II. Unlike its European helicopter contemporaries, Westland has also made a large effort in the hovercraft business so that Westland, with about 7,400 employees, is organized with British Hovercraft Corporation's 1,500 employees into the Helicopter and Hovercraft Group of Westland plc [12:77].

Westland is now one of Europe's leading helicopter manufacturers, but from 1915 up to 1946, the company mainly produced fixed wing aircraft. It entered the helicopter industry in 1947, by acquiring a license to build the Sikorsky S-51, which Westland manufactured as the Dragonfly. This decision was taken after Westland concluded that the future lay in helicopters. The technical association with Sikorsky has continued since that decision to concentrate on the design, development and construction of helicopters [13:285]. Westland's several other versions of the S-51 were produced for the Royal Air Force, Royal Navy, civil operators, and, eventually, foreign military and civil customers. Subsequent and current Westland designs are heavily dependent on collaboration with other companies [12:81].

In addition to U.S. technology, Westland received domestic design technology transfers through its government-

enforced merger with other British helicopter firms in 1960. Two of these, Bristol and Saunders-Roe, brought with them existing programs already in production, and all brought engineering expertise that led to the development of Westland's first domestic model, the WG-13 Lynx. Two earlier British designed models, the Wasp and the Scout, had been produced by Saunders-Roe prior to the merger. This aircraft was later included as part of a collaborative program with Aerospatiale that also covered that firm's SA-341 Gazelle and SA-330 Puma models.

Westland's links with Sikorsky were strengthened by the license to produce the Sikorsky S-61 Sea King, originally concluded in 1959. The Sea King still constituted some 20 percent of Westland's production output in 1980 [14:15], although Westland has made considerable changes in the power plant and specialized equipment, initially to meet a Royal Navy requirement for an advanced antisubmarine helicopter with prolonged endurance. The aircraft was also targeted at secondary roles such as search and rescue, tactical troop transport, casualty evacuation, cargo carrying and long range self-ferry [13:285]. A total of 204 Sea Kings and 32 of its tactical transport version, the Commando, have been delivered to the U.K., West Germany, India, Norway, Pakistan, Egypt, Belgium, Saudi Arabia, and Australia [12:81].

Westland's Lynx was one of the first products of the European multinational helicopter co-operative ventures.

Westland was the design leader and Aerospatiale the co-producer. The arrangement was confirmed in 1968 and the first aircraft flew in 1971. The aircraft was targeted at the intermediate weight range (7,000 to 15,000 lbs.) utility and naval roles. Lynx is a highly successful military program with approximately 70 percent of the production being performed by Westland and 30 percent by Aerospatiale [8:93]. Westland offered the Lynx to the U.S. Navy in the LAMPS II antisubmarine helicopter program competition before that program was cancelled. An improved Lynx was also offered in the U.S. Navy LAMPS III competition against the Boeing-Vertol and Sikorsky bids. The competition was eventually won by Sikorsky in 1977 with its Black Hawk derivative, the SH-60B Seahawk.

From the successful Lynx program (more than 310 unit sales to the U.K., the Netherlands, Qatar, Denmark, Norway, West Germany, and Nigeria) emerged a civil derivative, the Westland 30 (which retains 85 percent of the proven Lynx). The Westland 30 is an intermediate weight (12,000 lbs. plus) with 19 places, targeted to compete with the Sikorsky S-76, both worldwide and in the U.S. and the Aerospatiale SA-330 Puma. The Westland 30 was developed after Westland decided, in 1978, that all the military Lynx needed to become successful commercially was bigger internal volume. The subsequent derivative is aimed at ambulance, off-shore, VIP/executive and cargo versions [12:81].